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MAGNIFICENT MAVERICKS

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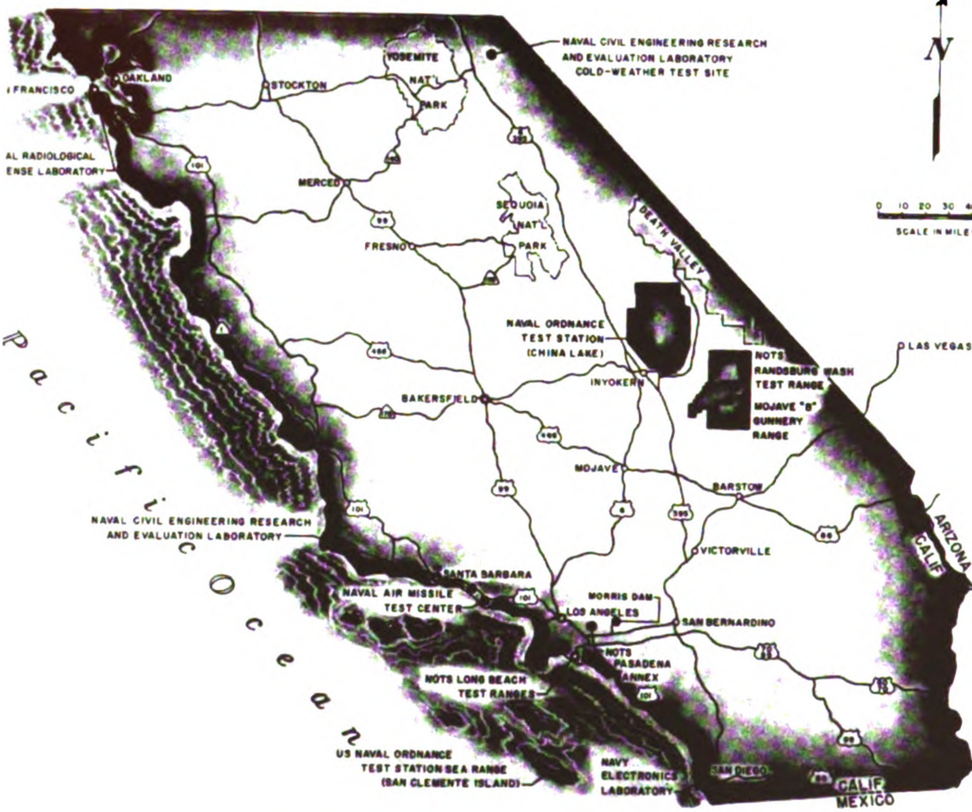

Locations of U.S. Naval Ordnance Test Station activities in the 1950s.

History of the Navy at China Lake, California
Volume 3

MAGNIFICENT MAVERICKS

Transition of the Naval Ordnance Test Station From Rocket Station to Research, Development, Test, and Evaluation Center, 1948–58

By

ELIZABETH BABCOCK

With an Introduction by

VICE ADMIRAL FREDERICK L. ASHWORTH, USN (RETIRED)

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Foreword

America is the land of heroes, rebels, and mavericks, and, especially during turbulent times, this combination has served our nation well. China Lake exemplifies the best of this tradition, and the early story of this "Secret City" is recounted in this book by some of its early mavericks.

In 1945, when Dr. L.T.E. Thompson became the first technical director for the Navy's new weapons research, development, test, and evaluation laboratory at China Lake, California, he brought with him a very deliberate philosophy of leadership that leveraged the strength of both the military and civilian scientists on the team.

Though his philosophy hinged on the marriage of two fundamentally different cultures, it blended the best of both—the art of the possible embodied by the myriad of scientific and engineering minds and the balancing and irreplaceable influence of the operational acumen represented by the warfighter. His philosophy was unique and imaginative, as well as unprecedented for the times, but it was perpetuated through the decades and still resonates favorably in the 21st century.

Magnificent Mavericks opens in 1948 when the Naval Ordnance Test Station (NOTS) was only five years old—still in its formative years. The stories herein are individually important, as they each capture key contributions that NOTS made to our national defense and the Navy in the 1948–1958 era. They also exemplify the early culture of NOTS, a culture of dedication, risk taking, speed, and, most prominently, innovation, determination, and dedication to the warfighter.

That culture was set by the attitude of its early military and civilian leaders. Internally, the leadership was tolerant of esoteric intellectual minds, was encouraging of independent thinking and innovative solutions, and was action oriented toward serving the military.

This attitude paid off big dividends in the station's response to an urgent need in 1950 at the start of the Korean War. An armor-penetrating rocket was designed, developed, tested, produced, and delivered to theater in one month—an extraordinary feat even by today's standards.

The NOTS solution employed many innovative, high-risk elements, and the response from station leadership when presented with the design approach was "Well, go do it." This spirit was not lost on the members of the station's early workforce. They knew it was something special, and they answered the call.

Externally, the early leadership was not so tolerant, especially with regard to the bureaucracies that existed within the Navy. The leaders were deliberate in every way to ensure that the station, as envisioned, became a reality and its legacy would live on well into the future. And, thus the maverick culture has its roots in the leadership spirit and technical acumen of early NOTS.

Mrs. Babcock does an exemplary job in capturing the critical underpinnings of these early technical and leadership successes—underpinnings out of which this early culture grew and that were initially fragile yet determined.

They were the realization of Dr. Thompson's and key military leaders' aspirations for a partnership between military and civilians that garners the strength of each—a vision that was in itself innovative and critical to the future success of the station.

The story of the *Magnificent Mavericks* is as pertinent today as it was in the 1950s. Just as in the aftermath of World War II, the U.S. military establishment today is confronting a need for serious change to address a new kind of enemy. The post-cold-war restructuring of the U.S. defense industry compounds this challenge.

Ironically, *Magnificent Mavericks* offers a "new" model for the future. Today, our weapons have significant capability but are often very complex and expensive. In addition, they must interoperate with a countless number of interconnected systems. They are built largely by sole-source industrial suppliers. *Magnificent Mavericks* tells of a successful approach that leverages both military-civilian and government-industry strengths; it also illustrates the successes of a government-industry collaboration in the development and production of weapons systems.

In sum, *Magnificent Mavericks* is the story of an innovative civilian-military vision coming to fruition—a vision enabling the creation of the nation's weapons capability in the 1950s, today, and in the future.

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Preface

This book, the third volume of the history of the Navy's desert installation at China Lake, continues the tale of a successful scientific and technological experiment that began in Volume 1 with the establishment of the Naval Ordnance Test Station (NOTS) and that continued in Volume 2 with the construction and early use of China Lake's instrumented ranges, pilot plants, laboratories, and community. Volume 1, *Sailors, Scientists, and Rockets* by Albert B. Christman, and Volume 2, *The Grand Experiment at Inyokern* by J. D. Gerrard-Gough and Albert B. Christman, were both published after NOTS became the Naval Weapons Center, and the series name was therefore established as History of the Naval Weapons Center, China Lake, California. The Naval Weapons Center is now the Naval Air Warfare Center Weapons Division. To avoid inconsistency now and in the future, this volume and subsequent volumes will be issued under the simplified series name, History of the Navy at China Lake, California.

When I volunteered to continue the inspiring story of the Navy's accomplishments at NOTS, I knew only that my book needed to take up the tale where its predecessor ended—with the 1948 dedication of Michelson Laboratory—and to end about 10 years later, a time span selected for the practical reason that doing justice to more than that productive decade would result in an impossibly thick book. As I began my research, I met with Gerald R. Schiefer, then technical director of the Naval Weapons Center, who advised me to "write about those magnificent mavericks who invented the Sidewinder missile and did all that other great work."

That valuable guidance resulted in not only the title but also the approach. Wherever I had the interviews, letters, or other reference materials to do so, I let the NOTS iconoclasts speak for themselves. I expect readers to find the magnificent mavericks of China Lake and its Pasadena Annex both entertaining and educational. Although memories may differ on the details, the NOTS pioneers display a remarkable unanimity on the value of the philosophy of individual initiative and teamwork that resulted in an amazing array of reliable weapons for the nation's defense.

Because the book describes events of half a century ago or earlier, many of the most vibrant participants are no longer alive. I wish I could present this volume to some of my most helpful sources of information, in particular Vice Admiral Frederick L. Ashworth, USN (Ret.), who died on 3 December 2005, leaving China Lake the thoughtful foreword to this volume as a parting gift. I also owe a deep debt of gratitude to Vice Admiral Levering Smith and Dr. Howard A. Wilcox, two China Lake pioneers who had agreed to review the book but who died while it was in preparation. Others now deceased who contributed to early drafts or assisted with photographs or facts included Richard V. Boyd, Jack Crawford, Dr. Emory L. Ellis, Dr. Walter B. LaBerge, Lee E. Lakin, LaV McLean, Peter F. Nicol, Captain Thomas F. Pollock, Leroy Riggs, Bernard "Barney" Smith, and Frank St. George. Warren Smith and Harley Tillitt made important contributions to specific sections.

I also owe much to the magnificent mavericks still living who contributed their recollections and expertise. Reviewing all or part of the first draft were Dr. Thomas S. Amlie, Dr. Edward E. "Mickie" Benton, Milton K. Burford, Dr. W. Frank Cartwright, William E. Davis, Dr. Hugh W. Hunter, Steven M. Little, Dr. William S. McEwan, Harold Metcalf, Ray A. Miller, Harold H. Patton, Lou D. Pracchia, Edward W. Price, D. Jack Russell, Robert G.S. "Bud" Sewell, Minchen "Mickey" Strang, Fred Weals, and Dr. James H. Wiegand.

Especially helpful comments came from two historians, former Director of Naval History Dr. Dean C. Allard and former Historian of the Navy Laboratories Albert B. Christman. In particular, I am grateful to Christman for the oral history interviews and reference materials he collected during his research for the first two volumes. Special thanks go to the reviewers of the final draft, C. John Di Pol, Franklin H. Knemeyer, and Leroy L. Doig III, each of whom possesses insight into China Lake's philosophy and programs that far exceeds my own and all of whom generously shared that insight in ways that strengthened the content and conclusions of my book.

Gerald R. Schiefer and William B. Porter, successive technical directors of the Naval Weapons Center, offered encouragement and support during the book's early phases, as did Stephen E. Sanders, then head of the Technical Information Department. Dr. Ron Westrum, author of *Sidewinder: Creative Missile Development at China Lake*, was generous in sharing insights, notes, and research sources, as was Dr. John D. Hunley, author of *Preludes to U.S. Space-Launch Vehicle Technology: Goddard Rockets to Minuteman III.*

Other notable assistance came from Mickey Strang, who voluntarily transcribed many oral history interviews after she retired from China Lake because she wanted to make a contribution to the NOTS history; from James M. "Jim" Koch and Robert "Bob" Campbell, who worked hard to help keep the project going subsequent to my January 1996 retirement from China Lake; from Debra "Debbie" Rios of the U.S. Naval Museum of Armament and Technology; and from Mary and Joe Adler, Barbara and Howard Auld, Gary Babcock, James J. "Jim" McLane, Felice Plain Mueller, Michael Kott, Mark Pahuta, Lieutenant Commander Joel Premselaar, USN (Ret.), Marilyn "Ditty" Riggs, Alexander K. "Sandy" Rogers, James Schmidt, George Silberberg, Gary Verver, Evelyn Wilcox, and Elva Younkin, who provided photographs, illustrations, suggestions, and anecdotes I would not otherwise have been able to obtain.

For suggestions and assistance during the early years of my research, I am indebted to the staff of the Naval Historical Center. The staff of the Technical Library at China Lake was invariably helpful. I am grateful too for the use of the photograph collections of the Maturango Museum and the Historical Society of the Upper Mojave Desert.

As my book neared completion, several people contributed their help and expertise, including Scott O'Neil, Naval Air Warfare Center Weapons Division executive director; Sandy Doyle, the excellent editor of the Naval Historical Center; Dr. Jean Bennett, the eagle-eyed final reader of the prepress book; China Lake employees Antonella Thompson and Tammy Kenady; and China Lake Museum Foundation volunteers Bob Campbell and Pat Connell.

Despite generous assistance from these people and others too numerous to name, I accept sole responsibility for errors in fact or in interpretation. In particular, I offer apologies to the numerous magnificent mavericks whose stories I did not include. I hope they will see the projects and events described in this book as representative of the teamwork and dedication they shared to make the Naval Ordnance Test Station an irreplaceable national asset.

ELIZABETH BABCOCK

U.S. Navy photo LHL 023747

Captain Frederick L. Ashworth with Sidewinder missile, 26 December 1956.

Introduction

The history of the Naval Ordnance Test Station, identified differently over the years but known more recently as the Naval Weapons Center, then the Naval Air Warfare Center Weapons Division, and now more popularly as simply China Lake, is an important record of the vision of a few civilian and Navy leaders who thought that there was a better way to conceive, research, develop, and bring to production naval weapons and weapons systems than the then more popular way of placing military requirements with industrial organizations and taking what resulted.

These leaders knew that warfare and the tools of warfare could be complicated and fraught with tactical and technical surprises. The genius of scientists might be able to unravel the technical surprises, but the military officers, by their profession, knew how to imagine how those tools could be used to fit their strategies and tactics of the warfare itself, knowledge totally beyond the experience of the scientific community. These military and civilian leaders needed each other, and the industrial world, in their opinion, was not the environment to bring these communities together.

A new concept of accomplishing this melding of these two communities had to be developed. The Bureau of Ordnance, as it was known then, pioneered by establishing the "government laboratories," of which Naval Ordnance Laboratory (NOL) at White Oak was the first. Then came the new Naval Ordnance Test Station (NOTS).

Volumes 1 and 2 of this history set the stage by describing the early years of the Navy-Caltech rocket program, the first wartime-spawned attempt to meld the academic world of scientists and the military into a research and development team. The first two volumes describe, as well, the construction of the test station, the early work that went on there, and the struggles made by NOTS supporters in Washington to ensure that NOTS would survive as a permanent research, development, test, and evaluation institution. Volume 3 chronicles the bringing to fruition of the idea of these early visionaries and the weapons that were conceived, researched, engineered, and tested at NOTS, then carried into production by industry and delivered to the Navy for use in war.

The dedication and drive of these early military and civilian leaders led to an institution based on simple premises. One premise was that trust is essential for an effective organization, trust between individuals and trust in the institution. Another premise was that the technical people should do "hands-on" technical work. Equally as important was the realization that technical work not based on experience of the prospective user could result only in the production of weapons that were not needed. Another important premise was that weapons developed would need to be simple, easy to use, easy to maintain, and highly reliable.

To support these premises, provision had to be made to permit and foster basic research in relevant fields of science. Facilities had to be available to carry out development testing of a new concept, engineer it toward a feasible design, and test the new concept on test ranges immediately available to the developer before the new weapon could be released to industry for production. Arrangement needed to be made to permit Navy and Marine Corps officers experienced in air and sea warfare to work with the developers to ensure that the finished product turned out to be innovative and useful when needed in war.

And finally, perhaps the most important of all, financial support had to be provided, unmanaged by people in Washington, totally under the control of the technical leader of the institution to permit that leader free use of his imagination while the institution experimented with any new and innovative idea that he thought might lead to a radical, perhaps, but useful weapon. Sidewinder was born by expenditure from such funding, the so-called "discretionary research fund."

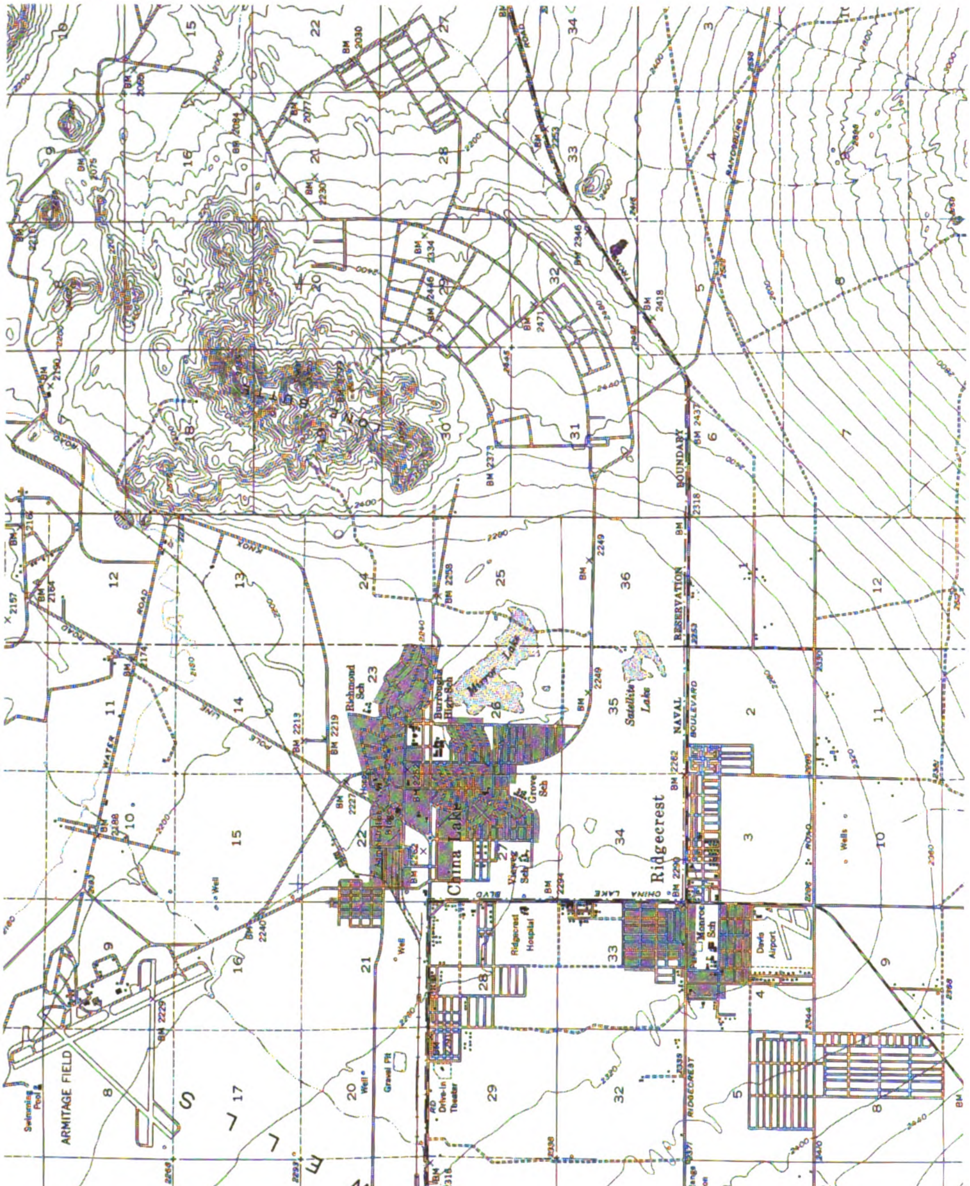
Novel in the vision of these leaders was how to structure and manage the new institution so that cooperative and effective day-to-day relations between the scientists and these experienced military officers would provide fertile ground to accomplish the results desired. A statement of principles of operation of the new institution was formulated and approved by the chief of the Bureau of Ordnance. In their simplest definition, the principles provided that these laboratories would effectively be civilian operations supported by the military, not only locally but also in the bureau in Washington. Simply stated, the principles provided that the technical activities were the range of responsibility of a technical director. The provision of support for the technical activities was the responsibility of a military commander. The commander and the technical director shared equally the responsibilty for the effective operation of the institution.

In any new and untried arrangement, both minor and major conflicts and misunderstandings can develop as the institution begins to mature, depending on the experience and personalities of the leaders. As readers of Volume 3 will see, the new institution was not without these growing pains. Strong military commanders with some technical training and outstanding military records found it difficult to avoid trespassing on the territory and responsibilities of the technical leaders. And as might be expected, some strong technical leaders found it uncomfortable to maintain the desired relationship with some of the military leaders.

Since things do not have to always be wrong, Volume 3 relates how the confluence of compatible partners in these leadership positions can have relatively spectacular results. Covering brilliantly a period from 1948 to 1954, Elizabeth Babcock has called her story of this period the time of the "Magnificent Mavericks," the archetypical excellent public servants who accepted challenge with courage, competence, and sometimes wild imagination. They proved that the atomic age had not made conventional weapons obsolete. Rather, many of their weapons were the strength of our military during the Cold War and since.

FREDERICK L. ASHWORTH
Vice Admiral, U.S. Navy (Retired)
Former Commander
Naval Ordnance Test Station

U.S. Geological Survey Ridgecrest Quadrangle, 15-minute series, 1953



Ridgecrest and China Lake in 1953.

The east-west length of the area shown is 10 miles. At right over the shoulder of Lone Butte (locally known as B Mountain) are the China Lake and Salt Wells Pilot Plants. In the upper left corner is Armitage Field, home of the Naval Air Facility. The village of Inyokern is about six miles off the center left edge of the map.

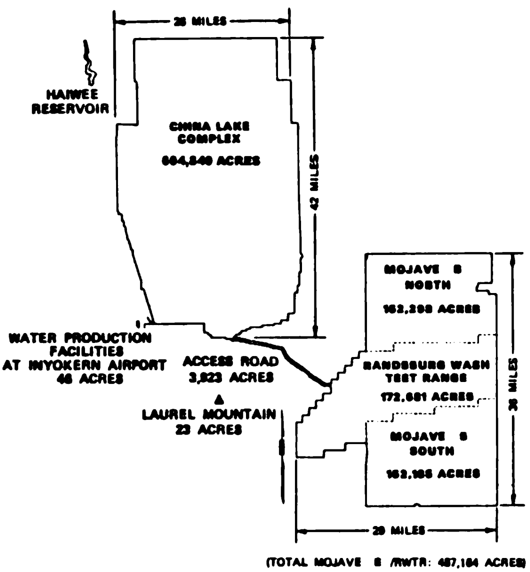
1

Rocket Station

The story of the Naval Ordnance Test Station (NOTS) in 1948–1958 illustrates the value of a tradition of rugged individualism and the proximity of trained people to laboratories, airfield, and ranges. As this book opens in 1948, the scientists and engineers at China Lake were working closely with combat-seasoned military people to accomplish pioneering work in rockets, fire-control systems, and propellant and explosive technology. At the heart of the station's success was the philosophy of military and civilian partnership articulated in the principles of operation and exemplified by the commanding officer and technical director.

Philosophical Bedrock

The Naval Ordnance Test Station, the vast Navy facility located in the remotest reaches of California's Northern Mojave Desert, started as an urgently needed rocket test station during World War II. By the end of the war, the station had become a permanent research, development, test, and evaluation laboratory, and by summer 1948 it was flourishing. Massive Michelson Laboratory, home to a host of research and development activities, had been completed earlier that year. Employees were working on rockets and components, propulsion and fire-control systems, and basic and applied research in physics, chemistry, aerophysics, metallurgy, and ballistics. Also crucial to the



U.S. Navy map courtesy John Di Pol

Navy real estate in the Northern Mojave Desert.
China Lake land area encompasses 1,096,005 acres.

productivity of the NOTS military and civilian team were the highly instrumented ranges and air facility only a few miles from the lab.

The station's advocates both on the desert and in Washington were struggling to keep the NOTS mission a broad one. The 1943 order that established the station stated its primary function as "the research, development, and testing of weapons." References to rockets in a draft version of the order had been scratched out because influential Navy thinkers did not want to limit the types of ordnance work the Navy might want China Lake to do. Ironically, however, spectacular successes in rocketry had pushed the station toward the specialization its planners had tried to avoid. In the minds of many, the development niche NOTS belonged in was labeled "rocket station." But missile testing—for the Bureau of Ordnance (BuOrd) and the Bureau of Aeronautics (BuAer) programs in about equal measure—continued to be a major activity.

Central to both the work and the philosophy of military and civilian teamwork during the station's early years was Dr. Louis Ten Eyck Thompson, China Lake's first technical director. A quiet man of average height and modest demeanor, Thompson was widely known as "Dr. Tommy," a nickname conveying both affection and respect. Mild-mannered, even courtly, in business dealings and social interactions, he nevertheless generally got things done his way. Those who worked closely with him praised him as an excellent politician who "really understood people."[1] Thompson had a Ph.D. in physics from Clark University, Worcester, Massachusetts, and a background that encompassed 19 years as the first Chief Scientist of the Naval Proving Ground, Dahlgren, Virginia. At Dahlgren he had formed close professional ties with members of the "Gun Club," an elite cadre of promising young naval officers assigned there for postgraduate ordnance training. The relationships Thompson established there later became one of the most valuable gifts he brought to NOTS.[2]

Perhaps the most important of these professional relationships was with Commander (later Rear Admiral) William S. "Deak" Parsons, who as Dahlgren's experimental officer was just beginning his illustrious career in the Navy's ordnance establishment.[3] Between them Thompson and Parsons developed a philosophy of military and civilian teamwork in research and development administration that had a profound influence over both men's subsequent careers, the principles illuminating the management of NOTS and indeed the R&D philosophy of the entire Navy.[4] Central to their concept was an idea Thompson expressed as "a kind of dreaming in those days that someday it would be possible to have a development structure within the military that was in-house." The two men agreed that such an in-house organization would

Dr. L.T.E. Thompson in 1951.

function at its most productive level only if it included laboratory, pilot plant, and range facilities and expertise.[5]

Soon after NOTS was established in the Indian Wells Valley on 8 November 1943, Thompson began working with Captain (later Rear Admiral) Sherman E. "Ev" Burroughs, the station's first commanding officer, to make that dream a reality. The Navy's new facility provided the setting for a military-civilian team to work under the authority of BuOrd. Many of the civilians were fiercely independent intellectuals from the California Institute of Technology (Caltech), and the chain of authority was a loose one, allowing for much independence of action. Lines of

Rear Admiral William S. Parsons.

communication were simple and direct, with only the chief of the bureau and his assistant chief for research (referred to as Re) in the line of responsibility leading from the NOTS technical director to the Secretary of the Navy.

The Bureau of Ordnance and the Navy's other two powerful material bureaus—the Bureau of Aeronautics and the Bureau of Ships (BuShips)—also operated with much independence. The bureaus had principal responsibility for the Navy's research and development activities, with the Office of Naval Research (ONR), which operated as a separate entity under the assistant secretary of the Navy for air, who had responsibility for overseeing research and development.

The bureaus were in the third organizational echelon of the executive branch, ranking below only the cabinet-level departments and the President himself. Each bureau chief enjoyed virtual autonomy in terms of both technical and business-management matters. The Navy was still under the bilineal system under which it had grown up, with the Chief of Naval Operations (CNO) having the authority to plan the needs of the fleet and issue statements describing operational requirements. The bureaus worked on those requirements, controlling and administering their own budgets and reporting directly to the Secretary of the Navy.

The Bureau of Ordnance had responsibility for design, development, procurement, and maintenance of defensive arms and armament for the control of guns, bombs, torpedoes, and rockets. Within BuOrd, NOTS reported to the assistant chief for research. Answering to Re were the R&D Division's eight branches, each having "cradle-to-grave" engineering responsibility for specific technical disciplines and products. The other two material bureaus were similarly organized. BuOrd and the station had only limited interaction with BuShips, but BuAer's responsibility for naval aircraft and related aeronautical material caused an overlap that would soon cause friction as guided-missile development became more attractive to both bureaus.

Thompson's initial modest annual salary of $8,750 as NOTS technical director increased to a more equitable $14,000 in September 1947, after the 80th Congress approved Public Law 313, allowing the pay of 30 leading civil servants to be established above that of the top civil service grade.[6] Dr. Ralph D. Bennett, technical director of the Naval Ordnance Laboratory (NOL) at White Oak, Silver Spring, Maryland, was similarly promoted. Supporters of the management philosophy represented by NOTS and its sister laboratory rejoiced in the promotions as tangible evidence of high-level support for the in-house laboratories.[7]

The additional prestige thus attached to Thompson's position as the station's technical boss reinforced the authority of the NOTS principles of operation, approved by the Bureau of Ordnance in 1946. The principles, created by Thompson and other station military and civilian leaders, recognized that the ultimate responsibility for all phases of NOTS' activities belonged to the commanding officer, but that control of the technical program should be delegated to the technical director. Thompson and his supporters in the bureau saw civilian authority over the technical work as crucial to recruitment and retention of the independent-minded scientists and engineers needed to carry out the station's demanding mission. Equally important was the military part of the team, which could draw on fleet experience to keep the technical work responsive to the practical needs of the Navy.

This philosophy, the very bedrock upon which NOTS was founded, allowed BuOrd to profit fully from the strengths of the career civil servants who applied their technical skills to think up and develop new ordnance concepts, as well as of the military personnel who provided valuable information on tactical requirements. Both roles were necessary at NOTS because the work encompassed all aspects of the research, development, test, and evaluation (RDT&E) process, with fresh ideas and information continuously flowing through the organization, a synergy of immense value to the quality of the end product.

From Commanding Officer to Commander

In practice as well as on paper, the station's principles of operation defined mutually supportive yet independent leadership roles for the commanding officer and the technical director, a concept that had the solid support of the Rear Admiral Albert G. Noble, the chief of the Bureau of Ordnance. For these principles to work, however, the station's top military leader himself needed to subscribe to them. In 1948 the station was fortunate that its military leader was Rear Admiral Wendell G. "Windy" Switzer, a suave diplomat whose calm, pragmatic management approach blended nicely with that of Thompson. Switzer understood well that he could not manage the independent-minded civilians under his aegis in the same way he ran the military part of his command.

Switzer had an appropriate background for his job: he was a Naval Academy graduate, an ordnance postgraduate, and a naval aviator with a distinguished record in World War II. His battle ribbons included the Combat Legion of Merit for action in command of *Wasp* (CV-18) against the Japanese homeland. As with several more controversial NOTS military leaders, speculation could

Rear Admiral Wendell G. Switzer and official visitors.

Switzer (left) welcomes Rear Admiral Albert G. Noble, Chief of the Bureau of Ordnance, and Hon. John Nicholas Brown, Assistant Secretary of the Navy for Air, to NOTS, 8 May 1948.

be heard that Switzer had been given "marching orders" upon his selection for command at China Lake. In other cases such orders were rumored to involve instructions to "get the civilians under control." According to station scuttlebutt, however, Switzer's orders were more positive: to reestablish the harmonious military-civilian relationships that had suffered a setback during the previous command of Captain (later Rear Admiral) James B. Sykes, who had declared his intention to run the station like a battleship.[8]

With memories of a turbulent era still fresh in their minds, China Lake's civilian leaders appreciated Switzer's stance as a quietly effective enabler who generally kept his hands off the technical work. Vice Admiral John T. "Chick" Hayward, who as a commander had been NOTS' first experimental officer in 1944-47, commented that Switzer had been sent to NOTS "to calm down the place . . . and so he did it, and he did a fine job." Perhaps even more to be appreciated was evidence that, as Hayward expressed it, Switzer was "persona grata for both Aeronautics and Ordnance" and thus unusually qualified to operate smoothly in Washington on NOTS' behalf.[9]

The question of whether NOTS needed an admiral or a captain to command it had been decided for the time being in favor of the higher rank.[10] An additional sign of improved status for NOTS and the Navy's laboratories at White Oak and Dahlgren came in November 1948 when the Chief of Naval

Operations directed that the military leaders of the three labs would no longer be called commanding officers, but would hold the more influential title of commander.[11]

Switzer took a direct interest in smoothing out some of the organizational rough edges remaining from the Station's formative era. To help this process, he educated himself in sometimes unorthodox ways. "Switzer was an interesting person in that he could dress in khakis and look like a per diem civilian any time he wanted to, and he wanted to rather frequently," recalled Roderick M. "Rod" McClung, a Caltech graduate who became a Station employee in 1946. According to McClung,

> He'd stand in line at the theater and talk to the people about where they worked, and nobody knew they were talking to the commander. He'd go to the mess hall and talk to the enlisted men. … He'd appear anywhere completely out of uniform, and chat with people, and that's where he got the information that he used, although he never would … tell you who he talked to. You just knew that he'd been around.[12]

The Leadership Team

The Thompson-Switzer team provided a smooth bridge between China Lake's early days, when each department head generally went his own way, and a new era of increasing mission complexity and more cooperative arrangements between the station's departments. In 1945–1946 Thompson had set up a workable technical organization headed by strong-minded, vigorous, and capable individuals: Hayward as experimental officer, Dr. Wallace R. Brode as head of the Science Department, Dr. Bruce H. Sage as head of the Explosives Department and boss of the pilot plants, and Dr. Arthur H. Warner as head of the Experimental Operations Department. On the base-support side of the house, Captain James A. Prichard, who became deputy commander in June 1947, provided capable management of military support, fiscal, personnel, and public works responsibilities. Although Dr. Emory L. Ellis, the Caltech scientist who oversaw China Lake's first rocket tests, reported to Sage, Ellis also functioned as one of the handful of leaders who worked together to establish an organizational environment conducive to creativity and productivity.

An important vehicle for communication among these powerful personalities was the Research Board comprising the technical director, the experimental officer, and the heads of the technical departments. The principles of operation described the board as the body that "reviews technical programs and advises the technical director with regard to their establishment and conduct."[13] Thompson, in the words of Dr. Hugh W. Hunter, executive

Research Board session, 1948.

Clockwise from left are Dr. Arthur H. Warner (blowing smoke), Dr. Bruce H. Sage, Dr. Pauline Rolf, William H. Saylor, Pierre A. Agnew, Lieutenant Chester A. Zimmerman, Captain James H. Hean, Dr. L.T.E. Thompson, Dr. John H. Shenk, and Commander Levering Smith.

secretary of the Research Board, "had a very interesting and difficult life with his department heads," but was able to use the meetings as a vehicle to achieve eventual consensus. "I've seen him in a meeting using words and words and words and words and talking and making sense, philosophizing until Brode would be squirming in his seat and Warner would be looking like he were half asleep," Hunter said. "But Tommy had something on his mind every single time and . . . somehow it was a way of just making these fellows sit there until they decided they were going to agree."[14]

Another somewhat less influential management tool was the Administrative Board, which Sykes had set up in March 1946 to deal with administrative policy. The first members of the Administrative Board had been the heads of Security, Supply, Personnel, and other support departments, but the extent to which administrative decisions affected the technical departments resulted in pressure to include the technical department heads on the board too. As the board size increased, so did the length of the sessions. "We'd start meeting about 9 o'clock in the morning and it generally ran on until 5 or 6 o'clock at night," recalled one participant.[15]

By 1948 the station's two decision-making bodies had nearly identical membership, and the Administrative Board's meeting frequency was declining. According to Ellis, the board's value was that it offered attendees from the support departments "a window . . . on the research and development work, where they found out what some of our problems were and where we would hopefully get some sympathetic attention."[16]

Technical Director's Right Arm

The experimental officer, a crucially important member of the military-civilian leadership team, advised the technical director on operational needs and served as military liaison between the commander and the technical organization as well as between the station, the technical bureaus, and aircraft contractors. The experimental officer and the officers assigned to him also contributed military savvy and extra horsepower to help get the work done. As Chick Hayward described the position, the experimental officer was "really the technical director's right arm."[17]

The experimental officer concept had originated at the Dahlgren Proving Ground, where that officer was directly responsible for the technical work, while the commanding officer and deputy commander were responsible for the administrative aspects. BuOrd took great care in its selection of a new experimental officer for NOTS, sometimes consulting BuAer in the process. Officers taking the job needed to be aviators who understood the complexities of BuAer and BuOrd turf struggles and, in Hayward's words, "knew how the Navy worked, and knew where the pressure points were, who they had to go see."[18] Some of the Navy's most promising officers rotated through the job.

Succeeding Hayward as experimental officer was Captain James H. "Red" Hean, whose brilliant early career boded well for his effectiveness as the station's prime link to the operating forces. Hean had graduated at the top of his class at Annapolis, had declined a Rhodes Scholarship in order to become a naval aviator, and had participated in the Caltech rocket program, shooting off the first retro-rockets ever fired from a U.S. aircraft. In World War II, as a member of Task Forces 38 and 58, he was in many of the major naval battles of the Pacific.

During Hean's China Lake tour, the already demanding experimental officer position was also assigned administrative responsibility for coordinating a management staff supporting both administrative and technical sides of the house. This assignment was complex and difficult, with the incumbent having to answer to both technical director and deputy commander across a broad and sometimes conflicting range of responsibilities. Among Hean's frustrations were the station's postwar land-acquisition problems and the hundreds of angry miners, cattlemen, and homesteaders displaced by the Navy.[19]

Succeeding Hean in July 1949 was Captain (later Rear Admiral) Jack P. Monroe, also a naval aviator and Annapolis graduate. Monroe had a somewhat less glamorous background than Hean, but one that appears to have better equipped him for the broad administrative challenges of his new job. Coming to China Lake from a tour as operations officer on the staff of Commander Aircraft, Pacific Fleet, he had filled positions of command both ashore and afloat and had seen action during World War II on the staff of Commander Carrier Division 2. He had been on board *Lexington* (CV-2) when it sank during the battle of the Coral Sea in May 1942. Monroe approached his administrative and fleet-liaison duties at NOTS with enthusiasm tempered by a healthy dose of pragmatism.[20]

Military and civilian leaders alike agreed that the concept of the experimental officer—a savvy military man who functioned as a bridge between the fleet and the technical staff—was a vital part of the station's success. "We got a lot from those guys," said one engineer. "Those guys had been out there, they'd been fighting, they knew what the problems were."[21]

Military Man in a Civilian Job

The military-civilian teamwork that characterized the station's leadership style depended to a large extent on implicit understanding of each team member's roles and functions. Yet Thompson was always willing to disregard tradition when he needed someone to fill a critical leadership slot. As a result, a coolheaded naval officer with a steel-trap mind arrived on the desert in September 1947 to spend the next seven years in a series of jobs that were usually perceived as inherently civilian in nature.

Commander Levering Smith later attained the rank of vice admiral in an accomplishment-filled career that culminated in management of the Navy's Special Projects Office and technical leadership of the Polaris and Poseidon fleet ballistic missile programs. A 1932 graduate of the Naval Academy, he served with distinction in the war in the Pacific, where he participated in 11 campaigns and engagements and observed early experiments with high-frequency radio communications and search radar. During a postwar assignment to Re, he directed programs in propellant development for guns and rockets. He soon developed productive relationships with Thompson and other China Lakers. In winter 1946–1947, Thompson began pressing Smith to come to the desert.

Captain Levering Smith.

Fortunately for NOTS, these urgings coincided with a growing conviction on Smith's part that he could have a greater influence on the outcome of the next major war by specializing in ordnance engineering than by continuing to rotate between sea and shore duty. Such a specialization would mean sacrifice. An engineering duty officer (ordnance) (EDO) designation meant a career path unlikely to culminate in an admiral's rank. But Smith never weighed considerations of status heavily in his career decisions.

He applied for the EDO designation, only to have his application languish in the bureau, awaiting a vacancy. Then he received orders to a sea command. "I decided to risk the transfer to ordnance engineering and gave up the orders to command the destroyer, recognizing that there was a pretty fair chance that that was the end of my promotions in the Navy," Smith recalled. "So that's how I came out to China Lake."

The job Thompson had in mind was as Sage's deputy in the Explosives Department. Smith's technical acumen in propellants and explosives made him an ideal choice for this position. He brought another asset to the job: a long-standing friendship with Sage. (Indeed, Sage had known Beulah "Boots" Smith since childhood and had been best man at the Smiths' wedding.) Thompson grasped an opportunity to use these technical and personal assets to solve a potential problem in the management of the Explosives Department.[22] After a hectic wartime schedule eased, Sage took on new activities in addition to two jobs he already had, squeezing in consulting work between responsibilities at both Caltech and NOTS. Thompson viewed these activities as evidence that sooner or later Sage would leave China Lake. When that happened, Thompson

Dr. Emory L. Ellis.

planned to put Smith in the Explosives Department job.

As if the normally civilian nature of the job and the potentially sensitive relationship with Sage weren't complications enough, the position awaiting Smith at China Lake already had a man in it. The assistant head of the Explosives Department was Dr. Emory L. Ellis, who personified the Caltech presence at NOTS. After earning a 1934 Ph.D. in chemistry and biochemistry from Caltech, Ellis became an analytical chemist for the Food and Drug Administration.

In 1936 he returned to his alma mater to do research in bacteriophage, which he believed would contribute to understanding the role of viruses in cancer.[23] Joining Caltech's preparations for the coming world conflict, he took charge in 1942 of a propellant and explosive test facility in Eaton Canyon, near to but independent of the main propellant extrusion facility managed by Sage.

When the Navy and Caltech selected the Indian Wells Valley in 1943 as the site of test facilities to replace Goldstone (dry) Lake and R&D facilities to provide weapons for aerial warfare, Ellis participated in planning the location of ranges, headquarters, and housing areas. Construction began even before the Secretary of the Navy signed the order officially establishing NOTS. Ellis, with a small crew of Caltech rocket-program employees, located and staked out an area to be cleared of brush and made other preparations for the first test, a 3 December 1943 air firing of live 3.0-inch rockets. Ellis continued as the onsite representative of all Caltech activities during the early evolution of the NOTS organization.[24]

In the early days, Ellis and his wife Marion hosted numerous get-togethers for early NOTS employees at their home at White Star Mine on a hillside overlooking the Indian Wells Valley. So many of these parties occurred that the

Ellis home was locally famous as the station's first (albeit unofficial) Officers Club. For social as well as technical reasons, then, Ellis had a place of special honor at China Lake.

Smith recalled that soon after he began work as deputy head of the Explosives Department, "I realized that what Dr. Thompson had asked of me was to step in between Sage and Ellis." Smith knew that his effectiveness at NOTS would depend on the delicacy with which he could make a place for himself between the two station pioneers without alienating either of them. "That was really the first position or job that I had that required earning the respect of those working for you," Smith said. "To a very considerable extent, in the military an initial respect goes with having been appointed to the job, whereas in civilian activities that respect has to be earned."

Fortunately, both Smith and Ellis believed in putting practical matters first, and Smith soon discovered that he was seldom needed for day-to-day department management. "Whether Dr. Thompson thought so or not, Emory Ellis could handle it quite well with Sage being there only part of the time," Smith said.[25] He decided to interpret the deputy's job in a way that would keep him usefully occupied and still give Ellis room to continue as before.

During Smith's previous assignment in Re, his method of managing project funds going to NOTS had matched well the informality of the desert mavericks. "The way you worked your money out with him was you sat down with him and told him what you needed to do the job," said one China Laker. "It was pretty clear that he was not trying to tell you what to do but to set up a money pattern which would make it possible for the work that was required. He essentially said, 'You do your technical job and we'll get the money.'"[26] Smith knew, however, that NOTS could use more knowledge of BuOrd funding procedures. He and a young assistant began work on improving the station's budget requests. This activity, he recalled, "didn't make us very popular. We had to ask a lot of questions to get the justifications BuOrd needed."[27]

Smith's BuOrd experience had given him valuable familiarity with the Navy's R&D planning system, which in 1948 was simple and functional, relying on only three types of planning documents. Planning objectives, issued by the Office of the Chief of Naval Operations (OPNAV), were broad statements of scientific and operational problems; operational requirements, also from OPNAV, were estimates of the performance needed for systems or equipment designed to solve operational problems; and research requirements from the Chief of Naval Research were statements of the need for scientific knowledge. Under this system, OPNAV stated broad requirements, and BuOrd and the other material bureaus retained full authority to plan and initiate R&D programs. The Navy Research and Development Review Board conducted annual program budget reviews to ensure coordination of priorities among the bureaus. With completion of this process, the bureau chiefs were responsible for justifying their budgets to the Bureau of the Budget and Congress.

Because Congress funded the bureau's R&D projects within the context of an overall program with individual projects not usually appearing as separate line items, the BuOrd chief had broad reprogramming authority. Times were changing, though. The establishment of the Office of the Secretary of Defense in 1947 had created for the first time a single official below the level of the President who had the authority to coordinate preparation and execution of the budgets for the military departments. This centralized authority was weak at first, but it was a sign of more budgetary centralization to come.[28] In the meantime, Levering Smith was there to help China Lake's technical leaders navigate the existing planning structure more smoothly.

Reaffirmation of Principles

By midcentury the station's organization and leadership were in transition. The self-confident Brode had left China Lake in early 1947 to become associate director of the National Bureau of Standards; he returned to the desert from time to time at Thompson's urging to take part in special studies. Hayward had departed in 1947 for Japan to study the effects of atomic bombing on Hiroshima and Nagasaki. During his subsequent distinguished career, Hayward became an important advocate for NOTS, keeping a warm place in his heart for the desert station he had done so much to form.[29] Prichard left in 1949 to become commanding officer of the Naval Ammunition Depot in Shumaker, Arkansas; he was succeeded by ordnance specialist Captain William Kirten, Jr.

Aside from Ellis and Thompson himself, Sage and Warner were the only two members of the top tier of NOTS civilian management to stay through the end of the decade. Each carved out a substantial domain at NOTS. The ruddy, mustachioed Warner had a Caltech doctorate in physics and lengthy experience on the physics faculty of the University of California at Los Angeles. An Army officer in both world wars, he had achieved the rank of lieutenant colonel. In World War II he had served on General Dwight D. Eisenhower's staff and had won international recognition for his contributions to the development of radar. He was never reluctant to speak his mind, rivaling his colorful colleague Bruce Sage in the force with which he pursued an independent agenda.

Like Warner, Sage possessed a Caltech Ph.D. He had joined the station in 1945 as head of the Explosives Department, and in an unusual arrangement also retained his positions as professor of chemical engineering at Caltech and as head of a program on hydrocarbon characterization for the American Petroleum Institute. Sage kept up with his three jobs by driving his well-maintained Mercury sedan at high speed between China Lake and Pasadena several times a week. He saved time on these trips by taking shortcuts, careening across the desert on two-track auto trails. To stay abreast of work at the China Lake and the Salt Wells Pilot Plants, Sage visited both plants, notetaking secretary in tow, at all hours of the day or night. China Lakers who worked with Sage found their interactions intellectually stimulating, if discomfiting. Warner later praised Sage's "endless energy," commenting further, "But it was sort of like a buzz saw . . . you didn't want him operating in your area."[30] Among the employees Sage was known as the "Great White Father," and each of the barrage of employee memos that followed one of his whirlwind trips to NOTS inevitably made reference to the wishes of "the GWF" somewhere in its text. Sage also pursued a follow-up memo system to ensure that employees responded within their assigned deadlines.[31]

As the station grew, new voices were heard at the Research and Administrative Board meetings. The leaders of the technical departments were reasonably satisfied with the informal, undocumented organizational relationships that linked functional and project groups across department lines. Difficulties arose, however, when Public Works and other service departments were asked to respond rapidly to conflicting priorities emerging from the technical departments. Switzer suggested that the time was ripe for a reexamination of organizational relationships and for a chart that clarified these relationships. Thompson cited an earlier caution from Parsons not to confuse an organization chart with an organization, but conceded that a chart was probably needed.[32]

Consequently, as NOTS' fifth birthday arrived in November 1948, the commander's staff had gathered ideas from Research Board members and was hard at work on a revision of its principles. The resulting station order, appearing that December, reaffirmed the precepts of the original principles but added new information on the organization by which these precepts would be carried out. The revision leaned heavily on the concept of accountability, using variations on the word "responsible" a total of 17 times as opposed to just once in the 1946 principles. The new principles added a description of the position of executive officer, successor to the deputy commander, who was stipulated as "the principal advisor to the commander for the military components."[33]

The new station order reaffirmed Switzer's responsibility to BuOrd for both managerial and technical control of NOTS, as well as to the Commandant Eleventh Naval District for "matters pertaining to military command and coordination control." In the revision, the technical director had "primary cognizance" over the station's technical organization. Thompson had previously been charged with "control," rather than "cognizance," a word substitution he could have interpreted as a weakening of his authorities. However, he was a full party to the change, which he may have seen as a better description of his job.

At Thompson's instigation, the new version of the operating principles established two new associate technical directors answering directly to the technical director and responsible for planning and coordinating the station's major work areas in engineering and in research and development. Thompson had been planning the change for several months and had already settled on the men he wanted in the two jobs: Wallace Brode for R&D, Bruce Sage for engineering.[34] After Brode declined the R&D job, Thompson decided to leave that position unfilled until he could find the ideal person for the job. For the following year, the associate director for R&D was listed on the organization chart, but with ". . ." where the name should be.

Sage took on the associate director for engineering position in January 1949, also staying on as head of the Explosives Department. He began his new job with his usual high energy and enthusiasm, but Thompson continued to fret about his dynamic colleague's propensity for collecting jobs that required him to be in several places at once. Later that year Sage's name disappeared from the Explosives Department organizational listing, and Levering Smith became the department's de facto head.[35]

Subsequent reorganizations were designed to facilitate a natural workflow, with Thompson functioning more as a leader than as a director. He was especially interested in fostering basic research within the context of a pragmatic technical organization and in assigning responsibilities to China Lake and to its annex in Pasadena in a way that would make the best possible use of the unique assets of both sites. The Science Department (renamed the Research Department in 1948) continued under its deputy department head, Dr. Christian T. Elvey, an astronomer with a strong interest in basic research. When the NOTS Pasadena Annex was officially established in July 1948, the Experimental Production Department was set up to carry on manufacturing operations in the Pasadena area and to take over China Lake's specialized shops and test equipment, which had been in the Science Department. Experimental Production was renamed the Design and Production Department in January

1949 with the arrival of a new department head, Donald C. Webster, formerly chief engineer of Librascope, Inc.

Within a few years, departments would change names several more times and the number of technical departments would triple, with recombinations of the Science Department eventually resulting in the Research, Engineering, and Technical Information Departments; with the Explosives Department splitting into the Rocket Development Department and the Propellants and Explosives Department; and with the Experimental Operations Department briefly renamed the Development Department and then split into three departments: Underwater Ordnance, Aviation Ordnance, and Test.[36] These and changes at lower levels of the organization occurred with a frequency that was cause for levity among the workforce. As one employee later commented, "There was always a reorganization going on! You used to hear that it was the Naval Organization Test Station."[37]

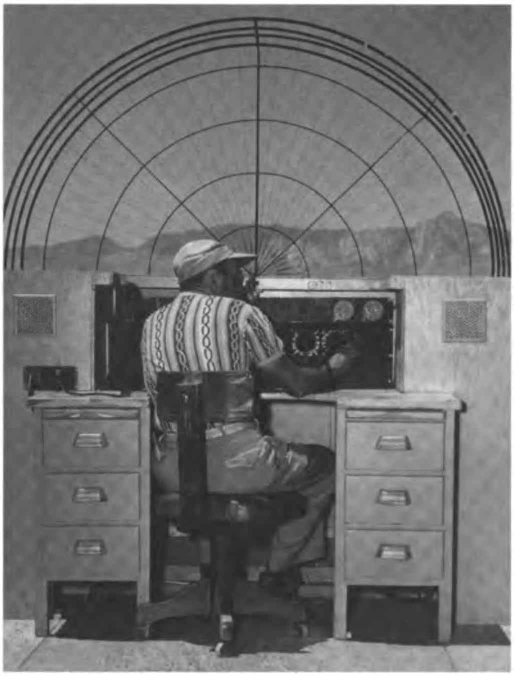
Taking Advantage of Physical Assets

People were at the heart of the station's smooth functioning, but nearly as important were the physical assets—instrumented test ranges, laboratories, shops, airfield—all necessary to the cradle-to-grave ordnance creation and support that were the station's reason for being.

The vast, remote landspaces that had attracted the Navy and Caltech to the Mojave Desert were as of 1948 still relatively primitive. With a few exceptions, such as the high-speed cameras designed by Caltech scientist Dr. Ira S. Bowen and Askania cinetheodolites "liberated"

U.S. Navy photo NP/45 32

Michelson Laboratory machine shop, May 1948. Laid out on the front table are components of the 5.0-Inch High-Velocity Aircraft Rocket (HVAR).


U.S. Navy photo NP/45 2252

Harp in use at B-1 Tower, July 1949.

The NOTS-developed device recorded aircraft position during bomb delivery on ground targets.

from the Germans at war's end, the ranges' crude instrumentation represented clever efforts to make do with what test conductors could scrounge or modify. Documentation for tests was often haphazard, with the signal to start a camera dependent on landline voice signal and operator reaction time. Station plans to install permanent range facilities began early, but the needs of the moment had priority. Range people coped with makeshift buildings and equipment—and still racked up an impressive record of testing successes.[38]

Although NOTS was at first shut out of the missile-development work that would soon become its specialty, missile testing—for BuOrd and BuAer programs in about equal measure—was always a major activity. In the immediate postwar period NOTS ranges supported one of BuAer's main programs, the radio-controlled subsonic missile Lark intended for shipboard launch against aircraft.[39] The program contributed numerous physical assets to NOTS ranges, notably a 450-foot eight-degree ramp of standard-gauge railway track, constructed in 1946 and referred to thereafter as the Lark ramp. Between Lark firings, station rocketeers used the ramp for exterior-ballistic tests of high-velocity rockets.

The Lark ramp discharged its cargo directly over the G-1 (live firing) and G-2 (inert firing) launching areas so that with each test these areas had to be vacated for safety's sake. (For range locations, see the map on page 228.) From the start, the plan had been to replace G-1 and G-2. But because the funding for permanent facilities was hard to come by in the frugal postwar era, free-flight firings continued from the G-1 and G-2 launching areas until 1955.

Test personnel were careful, and unsafe Lark launches happened only rarely. The exceptional misfire could be hair-raising. Guy C. Throner, who had come to NOTS in 1945 as an ordnance disposal officer and who had stayed on for civilian employment in the Rockets and Explosives Department, had vivid memories of one flight test:

> They launched a Lark, and it was supposed to go right and left and right and left down G Range. Well, it got no left signals. It got a right signal, and it turned and flew over the magazines, which had . . . thousands of tons of ballistite and bombs and everything else. . . . It took another right turn at the right interval and flew over the Salt Wells Pilot Plant. It took another right turn over the Salt Wells Pilot Plant and flew over the China Lake Pilot Plant. It took a right turn over the living area and landed 500 feet in front of the Lark launcher.

After the test participants were able to breathe normally again, one of them got on the phone to Throner and demanded, "Give us something to blow the damn things up." Such requests motivated Throner and other explosives specialists to begin work on a series of destructors, designed primarily to blast a missile into sections, terminating its flight when conditions became unsafe. Destructors were also designed to cut off fuel, cut control cables and wires, or sever instrument-carrying sections.[40]

U.S. Navy photo NP/45 24337

Lark fired from NOTS launching platform, 30 September 1949.

Meteor missile and booster on launcher, G-1 Range launching area, 20 July 1949.

When a fiscal 1948 appropriation allowed work to begin on the first permanent G-1 and G-2 launching facilities, construction activities made tests on the Lark ramp virtually impossible. A policy established in May 1948 limited Lark tests at NOTS to those where no other reasonable alternative was available. The station tested its last 16 Larks, not from the ramp, but from short- and zero-length launchers on the temporary G-1 Range. After November 1949 all Lark testing moved to the Naval Air Missile Test Center (NAMTC), Point Mugu.[41]

The end of Lark testing did not slow the pace of range work at NOTS, where tests of other missile programs were also going on. Two versions of the semiactive-radar-guided Meteor missile, each with its own type of propulsion system, were being developed under the technical direction of the Massachusetts Institute of Technology. Bell Aircraft Corporation and the Federal Telecommunications Laboratory were working on Meteor I, with its solid-propellant booster rocket to push it up to flight speed and its solid-propellant propulsion system to sustain it in flight. The longer-range United

Aircraft Corporation version, Meteor II, was to have a solid-propellant booster rocket and to be sustained by ramjet.

NOTS provided range and launching facilities, equipment for flight preparations, meteorological observations, and flight-test instrumentation for Meteor tests. The station's assessment group assisted Bell with data reduction and computation methods. Fifteen Meteor I flights occurred over a three-year period beginning in November 1948 when the first experimental test vehicle for Meteor was launched from G-1 Range.[42]

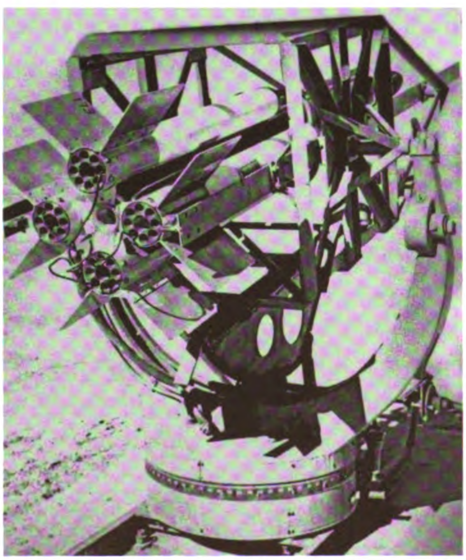
The station's superior instrumentation and vast acreage, which made safe missile recovery possible, brought tests of Dove to NOTS in preference to East Coast facilities. A general-purpose 1,000-pound bomb, Dove incorporated an infrared homing system that allowed bombing from altitudes up to 30,000 feet. Eastman Kodak Company had technical direction of the program. During the last two months of 1948, 19 Dove missiles dropped over NOTS from Douglas AD-1 Skyraider and Grumman F7F-3 Tigercat aircraft at an average altitude of over 30,000 feet. The test objectives were to obtain trajectory and missile performance data, and the station used its Askania cinetheodolites and Mitchell Chronograph cameras to keep track of each missile's exact flight path.

Recovery was still difficult, since the Doves plummeted from the heights with such force that they would plunge down through much as 30 feet of desert hardpan before coming to a stop. Eastman Kodak provided shock-packaged photo capsules for internal recording of missile functions, but the jolt of impact forced Eastman and NOTS to modify the photo capsules three times before coming up with a system that minimized film damage. As a result of this work, satisfactory film recovery from the last seven missile flights allowed the test series to be completed successfully. The last Dove test at NOTS occurred on 15 December 1948. The test program then moved to the Naval Aviation Ordnance Test Station (NAOTS), Chincoteague, Virginia.[43] But, as with all such test experiences, NOTS had gained knowledge and instrumentation from the experience.

Perhaps the most significant postwar missile tests at NOTS supported the pioneering Bumblebee program, which began as a ship-launched ramjet during World War II to counter the threat of Japanese suicide weapons in the Pacific.[44] The Bureau of Ordnance had assigned Bumblebee technical direction to the Applied Physics Laboratory (APL) of Johns Hopkins University in 1945. The program subsequently expanded to encompass three separate missile objectives: the Talos ramjet, based on the original Bumblebee specifications for intercepting aircraft targets at altitudes up to 60,000 feet and horizontal ranges from 10,000


U.S. Navy photo

Bumblebee firing from Lark launcher.


Courtesy U.S. Naval Museum of Armament and Technology

Searchlight base modified for first tests of Bumblebee guided missile.

to 100,000 yards; the Triton long-range ramjet bombardment missile, planned for use against land targets more than 400 miles distant; and the Terrier solid-propellant, supersonic beam-riding missile, planned as an interim weapon for use against attacking aircraft within a 5,000- to 15,000-yard horizontal range and a 30,000-foot altitude.

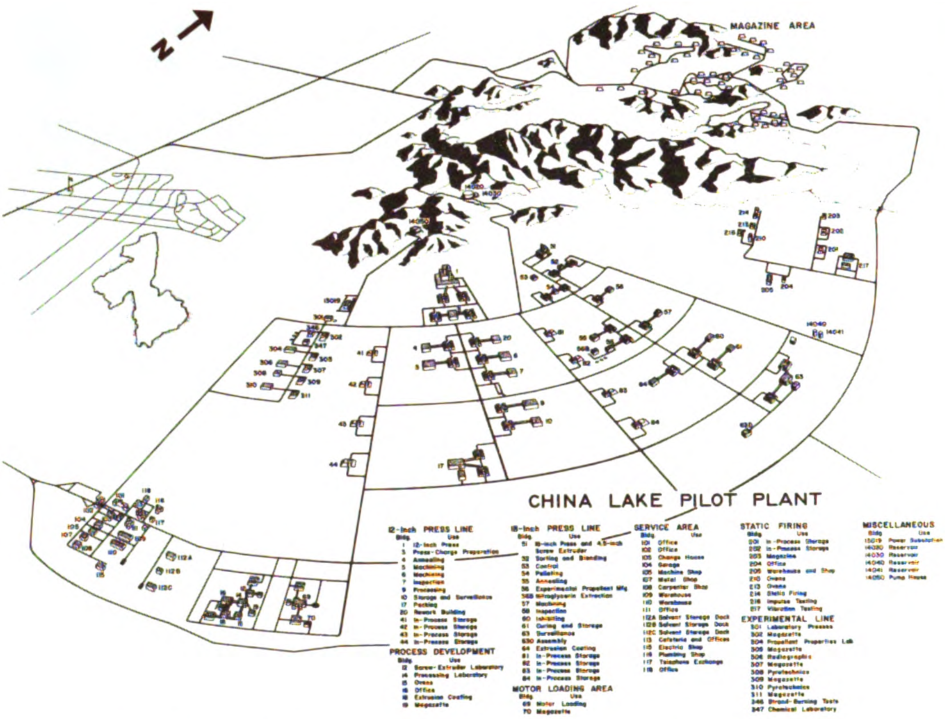
Just as with other missile testing programs, the flight of the Bumblebee needed to take place over dry land so that the test vehicles could be recovered. In the 37-mile-long G-1 Range, the station offered an instrumented flight line long enough for dry recovery. Between 1945 and 1952, more than 200 Bumblebee test vehicles flew over the sands of China Lake.[45] Program demands were broad, with several types of vehicles launched to test propulsion, ballistics, guidance, and ramjet ignition. Keeping up with testing needs became an increasing challenge. Launchers, radars, fire-control centers, assembly buildings, shops, magazines, electronic test equipment, and camera and telemetering stations were added between missile firings.[46]

In March 1948 the first two beam-riding flights to be conducted anywhere at supersonic velocities took place over NOTS ranges. Tests of Bumblebee vehicles necessitated such a heavy schedule that by January 1949, Dr. Nicholas A. Renzetti, head of the Measurements Division of the Aviation Ordnance and Test Department, was scheduling range time seven days a week, and Elvey added a swing shift for Research Department employees engaged in data-reduction activities.[47]

Another major use of the ranges involved the complex fire-control problems pilots encountered as they fired rockets in both air-to-air and air-to-surface attacks. Thousands of rockets had been fired at NOTS during the earliest years of the station's existence in attempts to verify Caltech rocket-sighting tables for the fleet. These tables helped pilots fire their rockets more accurately, but using the tables was a cumbersome, sometimes impossible process, requiring the pilot to consult a table strapped to his knee even as he coped with conditions likely to change at lightning speed. More sophisticated fire-control devices were clearly needed. By 1948 fire-control authorities in Washington had recognized the desirability of the station's expertise, clear flying weather, and physical proximity of laboratories and test spaces and had assigned NOTS the development responsibility for several fire-control radars and bomb directors. Responsibility for complete fire-control systems soon followed.[48]

But the station was about much more than getting the rocket to its target. Other facilities helped NOTS rocketeers build and improve every part of the weapon. Station innovations in propellants and explosives—the "go power" and the "blow power"—made a revolutionary difference in rocket design. These new designs were possible because the innovators could try out their ideas in China Lake facilities.

Development and experimental manufacture of solid propellants were crucial to the station's mission from the beginning. Pilot-plant facilities were among the first to be built at NOTS. The China Lake Pilot Plant (CLPP), referred to by China Lakers as "Clip," had been constructed as a joint project of the Navy and Caltech during World War II, and the hundred or so buildings



OPNAV Report 5750-5

China Lake Pilot Plant and its propellant-development facilities, 1950s.
The China Lake community and the Mirror Lake playa are shown in outline at left.

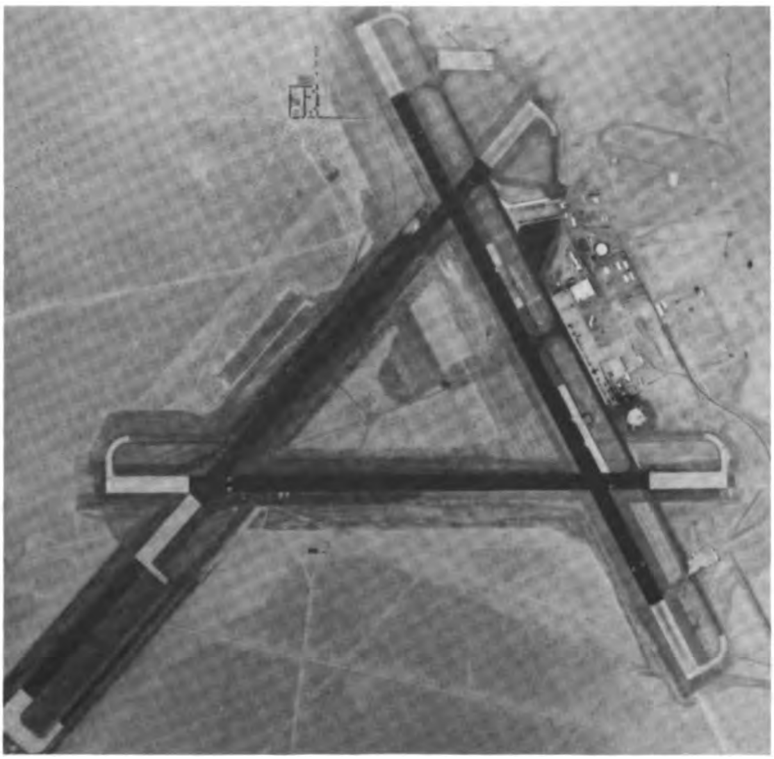
built in 1944 and 1945 on a long, arid, eastward-facing slope of the Argus Range, several miles to the east of China Lake, were intended primarily for rush production of dry-extruded propellant grains to support the Caltech rocket program. Extensive rocket-motor static testing facilities were also constructed in the area. The builders of CLPP kept in mind that China Lake assets would allow the Navy's leadership in solid-propellant technology to continue after the war.[49]

The foothills and mountains along the east side of the China Lake complex also proved their value as remote sites for testing explosives and warheads. A program to evaluate explosive-loaded rocket heads and fuzes began shortly after the station was established, and the first bomb-disposal officer on permanent-duty orders arrived in April 1944. The new bomb-disposal unit soon discovered that existing tools and methods were not suitable for the wide variety of ordnance-disposal tasks at NOTS. As a result, China Lake established Area R, an explosives test area that began a few miles north of the administrative area and extended northward in the ground-range complex. Military and civilian explosives specialists at Area R built their own welding shops, electrical shops, machine shops, wood shops, and firing barricades where they could study the fragmentation of exploded warheads.[50]

Another essential component of the ordnance life cycle was the Naval Air Facility (NAF), a permanent installation at Armitage Field just four miles north of the China Lake administrative area. Facilities at the field included three 10,000-foot runways, two hangars, a well-equipped shop, and all the equipment necessary to keep a stable of aircraft ready to meet NOTS' testing needs.

The airfield provided the pilots, aircraft, and services required to train flight crews and to conduct tests and evaluations of aircraft rockets, fire-control systems, and other systems and components. These assets, plus the excellent flying weather and proximity to the technical work, allowed NAF to function as a seamless part of the station's mission.

From the first days of its existence, NOTS had needed—and received—extensive help from the Navy's pilots and aviation support personnel. The station's first airfield (Harvey Field) had been built in Inyokern to meet urgent wartime needs for rocket testing and had been officially established as the U.S.



TS-59-200, Facilities Review, courtesy Howard Auld

Aerial view of the Naval Air Facility, China Lake.

U.S. Navy photo NP/45 21768

Naval Air Facility propeller-driven F6F Hellcat loaded with six 5.0-Inch High-Velocity Aircraft Rockets, May 1949.

Naval Air Facility, Inyokern, on 10 May 1944, with the move to the larger permanent airfield at China Lake occurring on 15 May 1945.[51] The Secretary of the Navy established NAF as a separate subsidiary command in April 1947.

The NAF commanding officer received fitness reviews from the station commanding officer. Several other permanent and temporary commands were also based at NAF at any given time, and the relationships of the leaders of those tenant commands and the NAF commanding officer were analogous to those of ship commanders at a Navy yard and the commandant of the yard.[52]

As with the military personnel assigned elsewhere at NOTS, the 28 officers and 308 men of NAF had an adjustment to make—one notable enough to cause the following statement to be added to the 1952 NAF Command History: "It is incumbent on all military personnel attached to this activity to realize the differences which exist in the Naval Ordnance Test Station organization as compared to the ordinary military establishment in which no civilians are employed in leading capacities."[53]

Navy pilots and enlisted men discovered upon their arrival at NOTS that they not only would be working hand in glove with civilians but would also be their neighbors in the community of China Lake. Both military and civilian team members frequently cited that social proximity as a reason for the success of their working relationships.

Rocket-Launched Potato Masher

Testing needs were the immediate motivator that brought the Navy and Caltech to the Indian Wells Valley in 1943. But the station was always about much more than testing. Innovative solutions to the needs of the fleet—"that's what NOTS was for," Levering Smith said.[54] The station was working on an amazing array of such solutions.

The specific innovations Smith referred to were in Weapon Able, or Weapon A, an antisubmarine depth charge whose distinctive, top-heavy shape earned the nicknames "the flying milk bottle" or the "potato masher." The Weapon A development stemmed from a BuOrd decision at the end of World War II that the Navy needed a new long-range rocket-propelled antisubmarine weapon to be forward-launched under sonar direction from a surface ship. The station started the project in mid-1946, with notable support from Caltech people and facilities at Pasadena, soon to become the NOTS Pasadena Annex. A complete Weapon A round was ready for ground firings by 1948.

The weapon presented difficult technical challenges, some caused by changing requirements from BuOrd. The station had responsibility for developing all Weapon A components except the magnetic-influence fuze, a Naval Ordnance Laboratory product that used nonmagnetic materials in the warhead and motor. When a proposed aluminum warhead proved unacceptable because of its high electrical conductivity, station engineers began experimenting with glass-reinforced plastic for the warhead case and aluminum for the motor tube, a pioneering use of such materials. The idea of using plastic and aluminum in high-pressure, highly energetic applications had little credibility in those days, so NOTS engineers were taking a risk to pursue these experiments.[55]

Weapon A team members were especially proud of their plastic warhead, a difficult design challenge, since the head had to be strong enough to withstand the ocean's pressures down to depths of 1,000 feet. The earliest heads were hand fabricated of plastic-saturated fiberglass. After discovering that the fiberglass could not be wound tightly enough by hand to avoid air bubbles, propellant experts devised a more satisfactory casting method. Ground firings in 1948 showed that the complete round was reasonably accurate.[56]

Since NOTS had fulfilled the task assigned by BuOrd, Sage suggested in June 1948 that the bureau be requested to terminate the station's Weapon A project and consider any subsequent work on the weapon to be a separate development project. The Research Board agreed. When Thompson returned from his next trip to Washington, however, he reported that BuOrd was

Preparations for Weapon A test at K-3 Crosswind Firing Range, 9 May 1951.

unwilling to let the station off the hook. Indeed, the bureau envisioned that China Lake would pursue a long-range Weapon A program.[57]

In theory, BuOrd's working relationships with NOTS involved bureau definition of the overall rocket requirement, with the station then coming up with the specifics. In practice, however, the initial idea often came from China Lake, with BuOrd reviewing and funding the weapon as the station developed it. But Weapon A was a different story. By 1949 all design specifications for the weapon were coming from Washington. The result was what Dr. James H. Wiegand, an Explosives Department expert in applied R&D of solid propellants, termed "a miserable business."[58]

The problem was that BuOrd drawings stipulated the design parameters for a 12.75-inch warhead, an exaggerated size considering that the launcher was already designed for a weapon of 5.25-inch diameter and that length was fixed by the between-decks height of the host destroyer.[59] Station rocketeers, working as well as they could within those specifications, finished a new experimental design by late 1949.

New Rockets for New Aircraft

Weapon A was just one of many innovative rocket projects occupying NOTS minds and hands. Military planners had seen the need for high-performance aircraft rockets since the closing days of World War II, when German jets armed with heavy nose cannons began attacking U.S. bombers from the rear, out of range of the bombers' tail guns. Under the Caltech rocket program, NOTS worked extensively on spin-stabilized rockets as possible countermeasures for both rear and frontal aerial attacks. Station rocketeers fired numerous spinners from the 1,500-foot track launcher at K-2 Terminal Ballistics Range. The results were disappointing. An initial slow spin signaled the rockets' instability. Once the spin necessary to stabilize the rocket was attained, centrifugal stress and unpredictable dispersion patterns resulted. To combat these problems, NOTS experimented with spinning the rounds while they were still in the launcher, but the necessary mechanisms were complex and cumbersome.[60] The 5.0-inch air-to-air spin-stabilized rocket known as GASR (General Aircraft Spin Rocket) was canceled, as were other spinners. However, as with many other such projects, the lessons learned in the spinner program paid off in later successful applications.[61]

What the Navy needed for its new aircraft were rockets that would be small, lightweight, speedy, and stable in flight. Caltech's 5.0-Inch High-Velocity Aircraft Rocket (HVAR) had been a success in World War II, with rockets by the thousands inflicting heavy damage on Japanese transports and defensive fortifications. As the war ended, more than a million HVARs had been stockpiled ready for combat use. But by 1945, aircraft speeds had increased to the point where more rapid rockets were needed.[62]

One thing slowing the HVAR down was its steel rocket tube. An aluminum rocket tube would clearly be preferable, but two major problems kept aluminum from being used. One involved the attachment of the nozzle and head to the tube. The heavy steel construction of earlier rockets allowed the use of snap rings, devices like the piston rings of automobiles that could be squeezed into double-depth grooves in the nozzle and head. Those components were then slid into the steel tube until the snap ring expanded, snapping into a prepared groove in the tube.

Even with the steel tubes, determining whether the ring was properly seated was difficult. The softer aluminum tubes made it impossible for the expanding rings to seat properly. Harold H. "Pat" Patton, head of the Ordnance Branch in the Explosives Department's Rocket Division, came up with a locking ring that permitted the use of shallower grooves and that later became standard for all internal-burning aluminum-tube motors.[63]

The other main problem with aluminum tubing was that if hot propellant touched the aluminum, it would lose strength or rupture. At war's end a double-base powder of nitroglycerin and nitrocellulose known as JPN was the principal solid propellant used in U.S. rockets. Each grain (propellant charge) of JPN burned on its exterior surface and was spaced away from the inside of the motor tube by longitudinal ridges of inhibiting material. With ignition, hot gases flowed toward the rocket's nozzle through the spaces between the surface of the grain and the inner wall of the motor tube. Until aluminum could protected from the heat of these combustion products, heavy, thick-walled steel motor tubes were necessary.[64]

Sage, Wiegand, and members of the Rocket Motor Section, which Wiegand then headed, came up with what Levering Smith termed a major breakthrough in rocket design. In a good example of the cross-organizational cooperation that marked the NOTS way of working, the Ordnance Branch and the Research Department's Chemistry Division together made the designs a reality. In 1949 Wiegand moved up to become head of the Explosives Department's new Propellants Division.

That was also the year that NOTS perfected a revolutionary internal-burning grain, which burned from the inside out rather than from the outside in. The propellant was cast over a mandrel that shaped the grain, and a central perforation, typically star-shaped, often eight-pointed, provided an initial burning surface area roughly equivalent to the final surface, thus maintaining pressure, and hence rocket thrust, throughout burning. By confining the flow of hot gas inside this perforation, the propellant acted as an insulator for the rocket case.

This major step forward was built on the pioneering work of Edward W. Price and Richard L. Noland, who had designed an innovative 5.0-inch rocket motor that was built, static-tested, and flight-tested at NOTS in early 1946. Price and Noland named the flight version "White Whizzer" in honor of the shiny aluminum motor tube and the unprecedented terminal velocity the rocket was able to achieve. At 3,200 feet per second, White Whizzer attained a velocity nearly twice as fast as that of the preexisting 5.0-inch HVAR (1,880 feet per second). White Whizzer


Courtesy Felice Plain Mueller

Edward W. Price.

combined several new features that later became standard in all ordnance rockets. White Whizzer was under the management of Caltech, but the entire program, including aluminum-tube manufacture, was accomplished at NOTS. Central to the rocket's novel design features were the aluminum tube and the extruded, inhibited propellant charge, incorporating Price's idea that a star-shaped perforation would eliminate combustion instability.[65]

Inherent to the internal-burning grain was a stable inhibitor (made of cellulose acetate or other slow-burning material) cemented in tape or sheet form to the grain's outer surface to prevent external burning. The inhibitor worked for newly made rounds, but with longer storage, performance deteriorated so markedly that the rocket could not be effective in use. The solution to this problem well illustrates the value of China Lake's hand-in-glove relationship between researchers and developers. Only at NOTS could the propellant staff turn for help to a research staff so familiar with the work that it was often already well on the way to a solution. In this case, Dr. William S. McEwan of the Chemistry Division and Dr. Eli Besser of the Propellants Division showed that the problem occurred because the cellulose acetate absorbed nitroglycerine from the propellant.

The station made a national search for a more satisfactory plastic, with plastic manufacturers submitting their confidential formulations along with samples of their products. Dr. Fred Ernsberger of the Chemistry Division evaluated the relative inhibiting values of these plastics and found only one material, an experimental plastic not yet produced in commercial quantities, satisfactory. The Navy had to build a plant for production of this product.[66] The inhibitor not only confined burning to the internal perforation, but also served as a minor reinforcement for the propellant by helping maintain the integrity of the grain as burning neared completion, thus helping defeat the problem of premature grain breakup that frequently resulted in erratic behavior.[67]

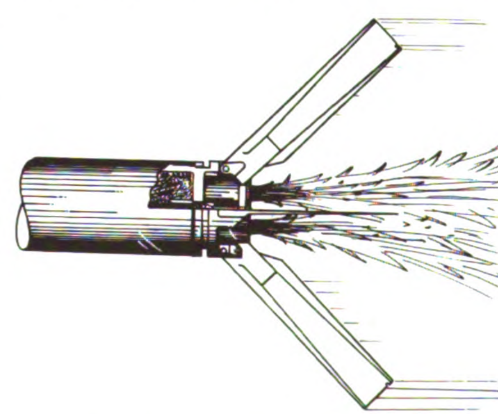
Building on the successful White Whizzer demonstration, NOTS had also achieved encouraging results with aluminum alloy as a possible motor-tube material for Weapon A. By early 1949 a prototype 5.0-Inch High-Performance Air-to-Ground (HPAG) rocket motor, incorporating an internal-burning grain and a light aluminum-alloy motor tube, had been manufactured and field-tested. The plan was that HPAG would eventually replace HVAR as an air-to-ground weapon. The new rocket's first intended use, however, would be as an antisubmarine weapon (HPAW) for patrol bombers to fire at submarines at shallow depth. The idea was that the rocket would travel 200 feet under water and have sufficient velocity to penetrate a submarine hull.[68]

As development of these and other rockets went forward, China Lakers' propellant innovations meant that motor tubes of aluminum or other lightweight materials could be used, allowing rocket designers to consider outfitting the Navy's aircraft with unprecedented numbers of rockets. Work on what would be the most successful of those new lightweight rockets—the 2.75-Inch Folding-Fin Aircraft Rocket (FFAR)—was already taking place.

Small but Mighty Mouse

For aircraft to carry rockets that could increase the hit probability by speeding in salvos toward their targets, stowage that would minimize aerodynamic drag on the host aircraft was also needed. Even before station brainpower solved the propellant and weight problems, postwar rocket designers had created a series of rocket and launcher designs that allowed rockets to be stowed either inside the aircraft or in streamlined external containers.[69]

Various Navy activities, Army organizations, and contractors had worked on the problem—not a simple one. Fins were necessary to rocket stability but could get in the way during stowage and launching. The first solutions involved fixed fins, which had the advantage of rigidity and ease of manufacture, but which extended rocket diameter and thus limited the number of rockets that could be stowed on the aircraft. The next idea was to design rocket fins that emulated an umbrella folded out of the way until needed. The fins had to be rigid to prevent flutter, capable of locking in the open position, small enough to fold within or behind the rocket until deployment, and of the right size and orientation to promote stability when they were open.[70]



Fins of 2.75-Inch Folding-Fin Aircraft Rocket in an open position.

NOTS had joined the search for a solution in 1946 with a BuOrd-funded applied-research program. Albert S. Gould, the quiet, competent head of the Explosives Department's Development Division, had been a member of the wartime Caltech team. He observed that pressure within the launching tube caused an Army spring-loaded mechanism to seize up with disconcerting frequency.

U.S. Navy photo

Patent presentation to Albert S. Gould for Mighty Mouse folding fins and their operating mechanism, 13 September 1957.

Gould (left) receives the patent from G. D. O'Brien, patent counsel, Bureau of Ordnance. Kenneth H. Robinson, head of the Technical Information Department, is at right.

Gould turned a potential liability into an advantage by using the pressure generated by the burning rocket motor to push four small internal pistons into operation. The pistons in turn forced open four fin blades the instant they cleared the launcher. Since both the acceleration forces outside the rocket and the opening force exerted on each fin by its piston were directly proportional to the pressure within the rocket motor, the system was self-compensating over the entire temperature range at which the rocket operated. The rocket with its fins closed was no bigger around than the diameter of the motor tube.[71]

The proximity of the test ranges to laboratories and machine shops meant that changes could be made and tested rapidly. An invaluable tool for refining Gould's folding-fin design was the K-2 experimental launcher 12 miles northeast of the China Lake housing area. As Gould and members of the Launcher Section under Hugo Meneghelli toss-launched inert models at various velocities from the K-2 rocket sled, they were able to look closely at how various fin shapes, nose contours, and head shapes affected rocket behavior.[72]

The station's first folding fins showed such promise that in March 1947 BuOrd requested development of a 3.25-inch folding-fin rocket, a diameter selected for the practical reason that NOTS already had a stock of tubing of that size left over from Caltech's World War II-era 3.25-inch fin-stabilized aircraft rocket.[73] In fall 1947 the bureau directed the station to split its small-caliber aircraft rocket program into three parallel lines of development. Work on a folding-fin version of the 3.25-inch rocket would continue, as would development of an interim fixed-fin version of 2.4-inch diameter (calculated to be the maximum size that could be stabilized by fixed fins contained within a

5-inch envelope). Most significantly from the perspective of the station's leaders, who had been pushing for an in-between size, NOTS also began design studies for a 2.75-inch folding-fin rocket, with further development work to proceed when the 3.25-inch rocket program had proved the folding-fin concept.[74]

As 1948 began, the station sent BuOrd a folding-fin design applicable to either a 3.25-inch or a 2.75-inch rocket. By March authorities in BuOrd's Ballistics and Bomb Branch (Re3) were convinced that the station's 2.75-Inch FFAR was the optimum design for service use.

The bureau's implementing memorandum assigned the FFAR first priority among NOTS rocket projects. BuAer had requested "an armament of 50 rockets" for a new interceptor aircraft then under design.[75] To fit in this aircraft, the memo said, the rockets needed to be individually carried in separate tubes and fired in 25-round salvos. Each rocket should have an outside diameter of not more than 3 inches and a length of 48 inches, a minimum burnt velocity (the velocity of the rocket at the time the fuel was depleted) of 2,000 feet per second, and a payload of about a pound and a half of high explosive to be detonated within the target structure by a contact fuze. Flight accuracy was not a requirement. Since the plan was to fire a swarm of the rockets toward the target, accuracy of only about 20 feet of error from a distance of 1,000 yards "is, in fact, desired for this round," the report said.[76] An analysis by the Research Department's Mathematics Division had already determined that an acceptably effective cluster could include as few as 12 rounds, but that 24 was the optimum number to produce a reasonable hit probability.[77]

The requirements in Re3's memo dictated the basic design features. With its high minimum burnt velocity, the rocket must be light in weight; the necessity for target penetration meant that the warhead and fuze combination must detonate within the target structure.[78] Finally, since effectiveness would depend on firing multiple rounds and on quality controls to ensure safety and reproducible performance, the cost and complexity per rocket must be minimized.

Rocketeer, 28 November 1951

Mighty Mouse cartoon by Paul Terry.

The rocket soon acquired the nickname "Mighty Mouse," a reference to cartoonist Paul Terry's tiny but powerful comic-strip character.[79]

With requirements firmly in mind, the NOTS team set to work on other aspects of the project. The first big payoff for the small, but mighty rocket would occur with the Korean conflict. In the meantime, those responsible for rocket development in Re3 began thinking that if small was good, smaller might be even better. In late 1948 the bureau asked the station to begin development of a 2.0-inch solid-propellant folding-fin aircraft rocket. NOTS analysis showed that a 2-inch-diameter rocket could cause a target aircraft to crash, but China Lakers squeezed the new assignment into an already busy schedule.[80]

Cooking Up Small Batches

Crucial to the station's major advances in rocketry were propellant innovations to lessen pressure variations with changes in temperature. NOTS propellant experts were confident that they could develop such propellants, but something had to be done to speed up the ponderous process by which new propellants were formulated, developed, and tested.

The absence of facilities on the West Coast capable of manufacturing experimental propellant lots forced the station to order experimental compositions from Picatinny Arsenal. With this arrangement, the process of planning, ordering, manufacturing, and shipping new compositions to NOTS for evaluation took about a year. Furthermore, Picatinny produced lots that were far larger than needed for initial tests of new propellants that would require numerous modifications before they were ready for production.[81]

China Lake's chemists and propellant developers were eager to use laboratory-scale methods, which would allow them to test new propellants in weeks rather than months and at a fraction of the previous expense. A small-scale processing facility, the 3-inch line, had been set up at CLPP in 1946 for nitrating glycerin, mixing slurry, and rolling 5- to 10-pound batches of sheet propellant. The 3-inch-diameter rolls the line could produce were too small to adequately simulate the full-scale rolls used in the large production plants.[82]

Sage grasped the occasion of the NOTS Advisory Board's first meeting in August 1949 to present the view that broadening China Lake's propellant program to encompass every step of the development process would benefit not just NOTS but the entire nation. Progress in propellant development was slow, he told the board, because nowhere could a propellant program be carried through from start to finish. "Until this is done, we essentially have no process control, and no one should be surprised at the variation between different lots of powder," he said. His listeners knew that process control was critically important because even a small variation could significantly affect a rocket's ballistics.[83]

A solution to the deficiencies Sage outlined was already under way. In 1948 Wiegand began planning for an experimental facility for small-scale solventless-propellant manufacture. He and propellant experts Quentin Elliott, Francis Warren, and Harry Connable designed the modifications needed to convert several of the buildings in CLPP's 3-inch line to allow the line to produce larger-diameter rolls.

Wiegand, Elliott, Warren, and Connable carefully scaled the equipment to ensure that the material it turned out would match that in subsequent large-scale manufacture. The completed small-scale manufacturing plant, unexcelled elsewhere in the country, included facilities for mixing and filtering small batches of propellant ingredients; drying, aging, and blending the resulting propellant paste; rolling this paste into sheets; cutting the rolled sheets into small pieces for extrusion in vertical presses; then heating and extruding these pieces into cylinders for evaluating mechanical properties and for explosive testing.

Following this manufacture, which could occur rapidly and inexpensively, NOTS solid-propellant experts could subject an experimental composition to rigorous physical, chemical, and combustion tests. Only after a new composition had passed these tests would it be considered suitable for pilot production and testing.[84]

Support for Research and Analysis

Underlying the hardheaded experimentation, development, and testing in NOTS laboratories, pilot plants, and airspace were the new ideas that came from looking ahead, from analyzing changing political requirements and technological possibilities. Thompson advocated strong NOTS involvement in planning and analysis. "We need more of and not less of this work if we are going to understand the environments of the future, the objectives of the future, and the constraints of any kind of conflicts—procedures, strategies, and tactics of the future," he said. Expressing his belief that "you can't do that best job in the best possible way unless you do know something about the criteria that have to do with what you select or don't select as characteristics of your weapon," he added that a small evaluation group was necessary to arrive at those criteria.

At first he had difficulty selling the idea in Washington. He summarized the bureau's reaction as "Oh, why don't you go back to Inyokern and build us some specific rockets that we've said we want. Why do you bother about these things. We'll tell *you*!"[85] Bureau Chief Noble, however, agreed with Thompson's arguments in favor of more autonomy for China Lake. In July 1948 BuOrd sent the station a memorandum indicating a desire to strengthen analysis and evaluation activity as part of the regular work at NOTS, an activity the memo said could be "more effectively carried out" at field activities than in Washington.[86] The station was already in the process of setting up a central Technical Planning Staff, and the BuOrd memo accelerated that process. What was not clear from the official correspondence was that the bureau itself had been pushed by the Department of Defense Research and Development Board (RDB), which in turn had been lobbied by Thompson.

The Technical Planning Staff, a small group of mathematicians, engineers, and operational analysts, began with the question of whether the station could develop a guided missile with minimum homing for rear attack, then expanded into two broad areas—maintaining contact with analysts elsewhere and conducting studies that focused on the effect of combat conditions on the station's choices in weapon characteristics. "Our objectives in this field are not primarily concerned with establishment of operations doctrine, but rather with specific conditions under which it is desired to have definite relative measures of effectiveness," Thompson said.[87] That first small analysis group would later grow into the Weapons Planning Group, a significant effort at China Lake.

Thompson also saw the area of research as deeply significant to the station's continued well-being. In 1948 perhaps two or three percent of China Lake's efforts went to basic research in areas related to those occupying NOTS development personnel.[88] Many of the station's early leaders and their supporters in the bureau considered research the backbone of the station's technical efforts. In March 1948 Noble wrote NOTS a strongly worded memorandum to that effect:

> I wish to make it a matter of record that I, as the Chief of the Bureau of Ordnance, and also the officers and civilian personnel of the Bureau of Ordnance, fully appreciate the necessity for the establishment and maintenance of a strong, important, and virile research program; and that in their respective fields Naval Ordnance Laboratory, White Oak, and Naval Ordnance Test Station, Inyokern, are not only invaluable, but are the principal source of authoritative competence in the Navy, if not in the entire United States.[89]

Thompson had another motivation for supporting basic research: he believed that good research scientists would stay at China Lake only if they had the latitude to work on the projects that most interested them. To the question of how closely such research should be tied to the station's development efforts, he answered that "almost any kind of research" was important, "since no one can be certain from what direction may emerge useful information for weapons of the future."[90] The key issue was in the balance of basic and applied research. Some members of the Research Board worried that if researchers had *carte blanche*, they might neglect the applied research necessary to support the development programs. In early 1950 the board articulated a research policy designed to strengthen the station's position as "a competent scientific center, with a healthy scientific atmosphere." The minutes explained:

> It is believed that high-caliber scientific personnel must have freedom to do a limited amount of basic research. Although the initiative for basic research projects must come from individuals, it is expected that the person doing basic research at a development center will normally be stimulated along those lines likely to influence the course of development programs.[91]

This policy emphasized linking fundamental studies with development. The Research Board further defined what that "limited amount of basic research" should be. A committee looking at the relationship between research and related development found 115 physicists or physical chemists in the grades GS-11 and above. Of these, only 20 were active professional researchers, a number

U.S. Navy photo NP/45 39898

Dr. Marguerite Rogers measuring tracks of protons in photographic emulsion, 1951.

the committee called "wholly inadequate . . . to carry out the programs undertaken by the Station." The committee also discovered few research projects in propellants, thermodynamics, warheads, or fuzes, fields in which the station needed competence. Furthermore, the committee said, the Research Department's work in basic physics was "concentrated in one field of endeavor, that is, studies of the light from the night sky to determine the state of the upper atmosphere."

The Research Board endorsed the committee's conclusions that more physicists should be hired, that "gadgeteers" should be transferred into other work, and that the station should concentrate its main research effort on work potentially applicable to rockets and underwater ordnance. In keeping with Thompson's philosophy, however, the board also endorsed continued support of the night-sky studies.[92]

At the heart of this decision was an agreement that the emphasis at NOTS would be on foundational research, studies undertaken with tangible goals in mind, a category somewhere along the fuzzy border between basic research, with its emphasis on formulating and validating theory, and applied research, with its applications to specific practical problems.[93]

In later years, such a loose interpretation would be superseded by the necessity to assign specific funding categories for all projects. In the years immediately following World War II, however, responsibility for coordinating the research programs of the bureaus lay with Office of Naval Research (ONR), which served as an early champion of Navy funding for basic research in both the Navy laboratories and the nation's universities.

In practice ONR exercised little authority over research at the individual laboratories, an approach that suited NOTS' iconoclastic scientists well. The August 1946 bill creating ONR had softened the new organization's authority after the material bureaus threatened to oppose passage on the grounds that the originally proposed wording would erode their authority to direct their own research activities. The bill had also established a 15-member Naval Research Advisory Committee, appointed by the Secretary of the Navy and responsible for advising the Chiefs of Naval Operations and Research on R&D matters.

The Station in 1948

As this book begins, then, the magnificent mavericks of NOTS possessed the leadership and support at home and in Washington, the funding, the organizational structure, and the facilities they needed to create the aerial-warfare products the Navy needed for defense of the nation. In the less than five years since the founding of NOTS, they had proved their competence in developing, improving, and testing new concepts and products. Now they were ready to pursue new challenges.

U.S. Navy photo by William Fettkether

Joshua trees and boulders in the mountains overlooking the Indian Wells Valley.

2

Life on the Desert

Living conditions in the Indian Wells Valley in the late 1940s and early 1950s—the desert's stinging winds, alien terrain, and lack of the usual amenities of civilization—drove some newcomers away. But many who stayed grew to love the place. The isolation of China Lake ensured that its residents would live, work, and play together. And despite the rigors of desert living—or, as some have suggested, partially because of them—morale was extraordinarily high.

Living With Nature

Visitors sometimes described the Indian Wells Valley, located in the Mojave Desert about 150 miles north of Los Angeles, as nothing but sand and dust. But the desert appeared lifeless only to those who didn't look closely enough. The Indian Wells Valley was home to more than 620 species of amphibians, reptiles, birds, and mammals, and Dr. L.T.E. Thompson's perception that "living here is quite interesting" was shared by many of his neighbors.[1]

Balmy summer evenings with brilliant star-filled skies and a subtle variety of natural surroundings were among the pleasures of life that for many balanced out the discomfort of howling desert winds and stinging clouds of sand that could blast away paint, etch windshields, and deposit a coat of grit on anything that didn't move, outdoors and in. When visitors complained of the three-digit summer temperatures, residents countered, "It's a dry heat." The low humidity made the desert's climate bearable, even preferable, to that of the sticky Midwest from which many NOTS workers had moved.

Rainfall averaged only 2.4 inches a year, with this dribble of precipitation usually occurring in late fall through early spring. Valley residents—except for hay-fever sufferers—rejoiced when winter showers were sufficient to ensure the springtime miracle of a desert in bloom. The most spectacular springs covered the hillsides of nearby Short Canyon with stands of poppies so dense, *Rocketeer* Editor Don Yockey said, that the canyon walls "looked like a tile roof."[2]

Beginning in 1945 the Women's Auxiliary of the Commissioned Officers Mess presented a wildflower show every spring. Vernon and Anabel Carr,

Evening snow and goldfields, tiny wildflowers found in the Indian Wells Valley each spring.

pioneering Inyokern residents, were among the wildflower enthusiasts visiting the most obscure niches of neighboring desert canyons to bring back dozens of species of blooms for this annual public display.[3] In years when winter rains came in enough quantity, the show included Fremontia, mariposa lily, and other rare blooms. Masses of the more common lupine, desert primrose, goldfields, apricot mallow, blue sage, desert hyacinth, indigo bush, and desert candle were displayed every year. The show, which typically attracted more than a thousand people from all over Southern California, offered a suitable inaugural activity when the China Lake Community Center opened on 1 May 1954.[4]

A rainy year had its drawbacks as well as its joys, as residents discovered to their horror in 1952, when an unusually wet spring inspired a horde of caterpillars to migrate across the blooming desert. Without the natural selection that sparse vegetation normally exacted, the proliferating caterpillars rampaged onto China Lakers' arduously maintained lawns. Walkways at the China Lake Pilot Plant became so slippery that work stopped until members of the Public Works Horticultural Branch could fight off the unwelcome intruders. Waves of caterpillars were succeeded by waves of ground beetles, which Darwin Tiemann, curator of the China Lake Museum of Natural Science, assured the community were "beneficial, eating butterflies and moths, though a nuisance."[5]

Such invasions were also likely to disrupt the station's test and evaluation activities. A 1954 *Rocketeer* article describing the instrumentation on the new C Range flight line noted that range engineer Duane Mack "has experienced only minor difficulty with ravens flying over his photoelectric stations but he is fervently hoping that the heavy rainfall this winter will not be a forerunner of a caterpillar and butterfly invasion similar to that experienced two years ago, as the flights of butterflies will trigger the photoelectric stations."[6]

In a community surrounded by raw nature, memorable encounters with desert wildlife abounded. Small boys relished these adventures, while their more cautious elders learned to accept such incidents with a degree of equanimity.

"We used to have horned toads and lizards in the refrigerator because if they'd cool them down, they'd ride the electric train without running away," Guy Throner remembered.[7]

Harold H. "Pat" Patton recalled an unnerving experience at the home of Beulah and Levering Smith (known to their friends as "Boots" and "Rosie"):

> My son Bruce was then about five, I guess, and we were going to eat out on the patio, and Boots and B. J. [Patton] were in the kitchen working on dinner . . . and Bruce, who was a great naturalist, who was always coming up with ants' nests under his bed, came in and tugged Boots' skirt and said, 'Mrs. Smith, do you want that snake under the table?' And she said, 'WHAT? Rosie!' Sure enough, under the table on the patio where we were about to sit down and eat dinner was curled up a sidewinder. And Bruce wanted it. He wanted it for his collection. Rosie and I went and got an old box or something and collared the sidewinder.[8]

Perhaps even more unnerving was a nighttime adventure famed Swiss-born balloon designer Dr. Jean Piccard reported to the *Los Angeles Times* after he visited China Lake in June 1952:

> In a story relating his hopes of eventually ascending to a height of 10,000 feet in a new balloon that he had designed, Dr. Jean Piccard reported that his latest problem, aside from raising $250,000 for the balloon ascension project is to identify a peculiar animal or insect he found in his bed while visiting at a nearby military base. . . . He described it as having 12 legs and being three or four inches long.

When a *Rocketeer* reporter asked the China Lake Museum for information on Piccard's experience, curator Tiemann suggested that the nocturnal visitor might have been a solpugid, a nonpoisonous member of the scorpion family. His explanation that the creatures were quite common, having been "found in beds on the station on previous occasions," no doubt did little to reassure Piccard.[9]

The Navy's Village

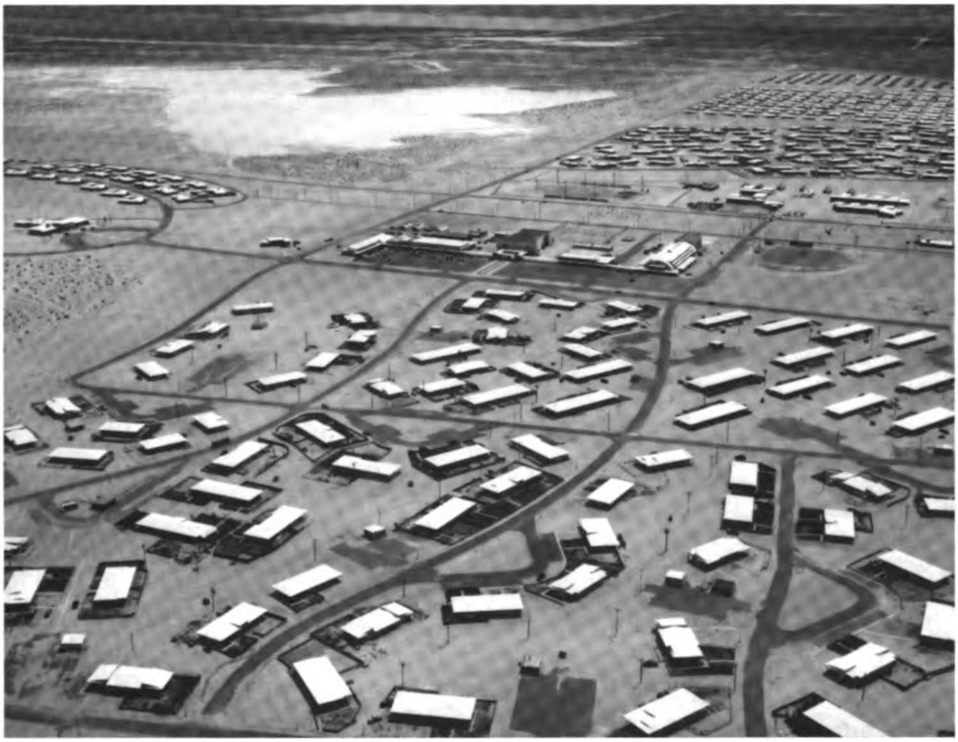
As the largest community built and run by the U.S. Navy, the "village" of China Lake presented unique management problems. The deputy commander ran the service organization, including the community, from the military side of the NOTS organization. But since about 80 percent of the employees were civilians, and since most of those employees resided in China Lake, the level of necessary community facilities and services fluctuated in direct response to the recruitment and retention needs of the technical organization.[10] For this reason, station civilian leaders also participated in community management.


U.S. Navy photo NP/45 14125

China Lake Community Manager John O. Richmond.

The day-to-day task of running the community was in the capable hands of John O. Richmond, who had come to the desert in 1944 as the station's first executive officer. Commander Richmond retired from naval service in June 1946 and stayed on as head of the Services Department until December 1948, when he became China Lake's first official community manager, with responsibility for controlling "all matters which concern the operation, administration, and welfare of the community and its related activities," including the Fire Department, housing and recreation services, and a kaleidoscopic variety of community-management challenges presented by spirited residents.[11] Whenever a resident needed plumbing or home repair, a call to 7177 would bring someone from the Public Works Department in a gray Navy truck to make the repair.

During the early days of hurried construction, wartime expedience necessitated that the Navy furnish its tenants with furniture, landscaping services, lumber for fences, and other necessary materials and services. With construction completed, employees were encouraged to help themselves to whatever seemed usable from a substantial mound of scrap lumber at the "boneyard."[12] By the time the community was well established, the expectation that the Navy would provide for such needs was equally entrenched. Many residents regarded pilfering of small items, or "cumshaw," as one of the benefits of living at China Lake. "If you wanted to take a typewriter home, you could take it home, and there were those who didn't necessarily take them back," LeRoy Jackson recalled. The "can-do" attitude that the station's employees brought to their jobs carried over to home-improvement projects, where the prevailing philosophy was that there was nothing wrong with appropriating Navy materials to improve Navy housing. "Since everything belonged to the government, your assumption really was that it didn't make much difference if it moved from one place to another," said Jim Wiegand. "So rocket boxes and every other kind of wood appeared as fences, and I don't think that very many people bought many nails or anything else in those days."[13]



Community of China Lake, 14 April 1948.

Bennington Plaza, with its gym and shopping complex, is at center. To the left at the end of the street is the Commissioned Officers Mess, now the U.S. Naval Museum of Armament and Technology. The Mirror Lake playa (dry lake) is at upper left.

By 1948 the Navy had begun a long and arduous process of withdrawing some of the benefits that became available elsewhere as the community grew. For example, even though China Lake had a small post office at Bennington Plaza starting in 1945, home delivery of mail was not available until June 1948. Before that, mail arrived at the workplace, so that an employee might come back from lunch or an appointment and find that a mail-order tire had become an impromptu paperweight on his desk. Such deliveries increased the difficulty of keeping the Navy's items and personal property separate. With home delivery, office delivery of personal mail gradually abated.[14]

A Vehicle for Community Representation

While Richmond kept the community running smoothly and made logistic and policy recommendations to the command, the residents of China Lake had their own vehicle for influencing community governance. The Employees

Welfare Association (EWA) was established in November 1945, apparently as an outgrowth of employee meetings Commanding Officer James B. Sykes instituted as evidence that he was interested in the opinions of China Lake's obstreperous civilian population.[15]

The association was designed to promote civilian welfare and to act as a liaison between civilians and the Navy. Representatives, elected in a ratio of one for each 50 employees, in turn elected a 14-member board of directors that functioned in certain respects like a city council, making recommendations to NOTS command.

During the first years of its existence, EWA concerned itself with housing rental rates; postal, medical, and veterinary services; and access to shopping facilities. A gala Fall Fiesta was the organization's primary source of revenue during the years 1947–1954. Every October crowds of up to 10,000 swarmed in for air shows at Armitage Field and barbecues, dances, and drawings for automobile prizes at Bennington Plaza.[16]

Perhaps the most significant accomplishment of EWA was the NOTS Employees' Federal Credit Union, which received its charter on 26 November 1947 with total assets of $45—a $5 share deposit from each of its nine charter members. Its first loan, made a few days later, was for $10, an amount needed to tide a member over until payday. Rod McClung recalled that when his wife, Lorraine, excitedly reported on this new investment possibility, he decided to

Courtesy Historical Society of the Upper Mojave Desert, Bette and Larry Fox collection

Second China Lake Fiesta, 15–18 October 1949.

U.S. Navy photo NP/45 42946 courtesy Nancy George

Temporary school buildings at China Lake, October 1951.

investigate. He found that the organization's administrative assets consisted in their entirety of one file cabinet, one desk, and one employee, who worked a grand total of two hours a day. Nevertheless, the McClungs were among many China Lake residents who decided to become members. Assets grew rapidly—to more than a million dollars by the credit union's tenth anniversary.[17]

In 1949 NOTS command extended the right to vote for EWA representatives to all adults living in China Lake, not just station employees; this change gave the entire community a voice in its own representation. To reflect the broadened member base, EWA was renamed the China Lake Community Council in April 1950, and the community was divided into precincts to elect representatives to serve on the council.[18] Although not privy to most of the policy decisions affecting the community, the Community Council did serve as a sounding-board for the NOTS command on matters affecting the community. Council recommendations led to improvements in recreation, medical service, mail delivery, restaurant service, school districting, and telephone service. Captain Walter V. R. Vieweg described the council as "the one agency to which I turn when the collective opinion of the community is needed."[19]

Because of the paucity of community services in China Lake's early days, NOTS command permitted civilian employees and their families to use the commissary store and the Navy Exchange, facilities normally reserved to the military. These special shopping privileges were a constant source of irritation to merchants in Ridgecrest, the growing community just outside station boundaries. As a result, one of the council's most important contributions was in the area of

China Lake main gate, 1954.

U.S. Navy photo LO 5268, courtesy Maturango Museum, Erma Peirson estate

communication with Ridgecrest merchants, particularly at times when relations were strained.

"At first there was hardly any community of Ridgecrest . . . all of our activities were right there on the base, and there were a couple of establishments out in town that we would go to every so often, but it was a rare thing," recalled Tina Knemeyer, who arrived on the desert as a young teacher in 1945. She remembered that as the community grew, resentment flowed in two directions. Local shopkeepers complained that the Navy was an unfair competitor, offering goods and services at prices that private entrepreneurs could not match. And China Lakers resented what they labeled as efforts to perpetuate a shopping monopoly with high prices and poor service.[20] Many decades would pass before most China Lakers saw shopping as something that could be accomplished locally.

Society at China Lake

The newness and isolation of the community, the general lack of air conditioning, the likelihood that a work day beginning with meetings and phone calls might end up out on the range, and the iconoclasm that was a legacy of the Caltech team all contributed to the informality of the NOTS organization, where a workplace truism held that anyone dressed in a suit was either a salesman or an official visitor.

The social milieu of the officers' and scientists' wives in the 1948 era, however, was quite another matter. The words "Desert Casual" that would soon become the dress normally specified on party invitations as yet appeared infrequently. Social arbiter Emily Richmond, wife of the community manager, insisted on a dress standard that included white gloves for afternoon teas. Dinner parties and women's club meetings were also frequently dressy, with Mrs. Richmond thus ensuring that a certain graciousness enhanced what was

U.S. Navy photo NP/45 44310

U.S. Navy photo

China Lake cocktail parties.

Top, from left, Alice Zilmer, Slim and Sylvia Winslow, and Dorothy and Ted Toporeck dress up in November 1951 to celebrate the station's eighth anniversary.

Bottom, from left, are Beulah "Boots" Smith with an unidentified friend, Elizabeth "Liz" Robinson, and Captain Levering Smith, early 1950s.

otherwise a rustic lifestyle. "We never went anywhere to a party after 5 o'clock without our white gloves," Boots Smith recalled, adding that she was pleasantly surprised upon her arrival at China Lake to discover "such beautiful etiquette and manners out in the middle of the desert."[21]

An important part of community life for the wives of officers and civilian scientists alike was the Women's Auxiliary of the Commissioned Officers Mess (WACOM). Kay Burroughs, wife of the station's first commanding officer, had started the organization as a replacement for both the Officers' Wives Club normally found on a Navy installation and the Faculty Wives Club the wives belonged to in Pasadena. The commander's wife was traditionally the president of WACOM, and the organization provided a vehicle for military and civilian wives to work together on the wildflower show, first-aid dressings for the Station Dispensary, teas for newcomers, and an annual County Fair.[22]

Although certain activities—entertaining visiting VIPs, for example—were expected of the wives of station leaders, natural community leaders also emerged regardless of husbands' positions. Community volunteers scored huge successes with events like the June 1948 All-States Dinner, which drew more than 600 people to Sandquist Spa, a recreational area built on the site of a former ranch.[23] The wives worked hard to ensure that schools and other social services provided the amenities necessary to a well-functioning community. "The women really started that community," said Lois Allan, who in 1945 had been the bride at the first wedding reception held at the NOTS Officers Club.[24]

The wives of China Lake employees also started the valley's first mental-health organization. In 1947 a study group of the China Lake Branch, American Association of University Women, looked into the mental health situation

Courtesy Historical Society of the Upper Mojave Desert

China Lake volunteers with young polio victim, 21 March 1950.

Dr. Harriet W. Nielson (center) of the Ridgecrest hospital accepts a donated record player from Mrs. Harold Ratay, Mrs. Edward Ashburn, Mrs. Arlo (Jay) Mueller, and Mrs. John (Gertrude) Vanderbeck. In the bed is four-year-old Judy Todd, daughter of Mr. and Mrs. Louis Grosshardt of Ridgecrest.

and was horrified to discover that local children were waiting for as long as a year after their initial interviews for treatment in Bakersfield. When Virginia McDonald was invited three years later, as AAUW president, to sit in on a budgeting session of the local Community Chest, she was in a good position to suggest that money earmarked for emergency relief might better be spent for counseling services.

The Community Chest board of directors, swayed by her pleas, allocated a sum of $1,000 for a counseling service "providing a trained social worker and suitable facilities could be found." In a fortunate coincidence, Dr. Eli Besser and his wife Sylvia, an experienced social worker, had just arrived in China Lake. Sylvia Besser agreed to work a day a week for a year. AAUW members obtained permission for her to use the Red Cross sewing room at the Station Dispensary for her office. In January 1951 the Desert Area Family Welfare Service began operation. The first year's budget amounted to $1,347, with 93 individuals receiving counseling.

The following year, after agreeing to double her time worked, Besser counseled 201 people, spending far more than the time she was paid for. Then in 1956 the board of directors hired a secretary and a second trained social worker, Betty McDaniel, each for a day per week. With that help, the agency could handle 25 to 30 interviews a week—a heavy load for a part-time staff.

Getting financial support was a struggle, particularly before federal aid through a state agency was obtained in 1956. When that aid arrived, Besser increased her workload to three days a week, and a caseworker was hired for two days a week. Desert Area Family Welfare Service set up operation in the NOTS Training Building and began full-time office hours. Financial support from the United Fund also helped. Besser left the area's first mental-health agency in 1957 to take a position as a personnel consultant to pupil personnel service at Burroughs High School. After that good start, several mental-health agencies continue to offer their services in Ridgecrest today.[25]

Intertwined Social Lives

Unlike the professional employees and military officers who occupied the upper stratum of China Lake society, many enlisted personnel and lower-level civilian workers saw life in the Indian Wells Valley as highly stratified. For those with minority ethnic backgrounds, social life on the desert could resemble a closed club they were ineligible to join. In an unusually overt example of discrimination, a NOTS civil servant who was black encountered a "We Cater to White Trade Only" sign when he went to lunch in 1952 with fellow workers at a Ridgecrest cafe just outside the China Lake main gate. After the civil servant complained to the NOTS commander, the Ridgecrest Chamber of Commerce prevailed on the offending merchant to remove the sign and apologize.[26]

What stratification there was at China Lake was by type of job, not by race, since housing assignments were made by military rank and civilian pay level. Jim McLane, who arrived in June 1951 as a recent graduate of the University of Wisconsin, later commented on that aspect of community life:

> There was a class thing going on here because you had to be a certain rate in order to get certain housing, and you had to be a certain rate to get into a certain club . . . . That was the way things were, and nobody really worried about it particularly. It was a community as a whole, and it didn't really make any difference who your neighbors were. You were good friends. You all had the same problems. You still all tried to get the fence material from Public Works and the sprinklers fixed, and you had air-conditioning problems the same, and everybody had rental housing. You were all on an equal footing, and it made for, I think, a lot of camaraderie on the base.[27]

The proximity of housing to the workplace also fostered dedication to the job—both a blessing and a curse for the social fabric of the young community. In looking back at their first weeks and months at China Lake, wives of station employees frequently recalled that their husbands disappeared into the lab almost immediately and that their lives revolved around their jobs. For the wives, adjustment was sometimes difficult.

"We were all very intense in those days," said John Boyle, who came to NOTS from Minneapolis in 1951. Husbands worked a couple of days straight if the job required it, and "marriages broke up there at China Lake, not only because of the isolation and the horrible weather, but because of the fact that the men gave everything to the job and some of the women weren't about to put up with it." But Roseanne Boyle, the "darling Navy nurse" Boyle met soon after he arrived on the desert, and other wives who tolerated the living conditions and the demands of their husbands' jobs soon appreciated the close-knit lifestyle that made China Lake "a wonderful place to bring up kids."[28]

Taxpayers "gained a great bargain in unpaid work at China Lake," Bernard "Barney" Smith said. "Wives may have complained because their husbands found it too easy to go back to the lab out in the desert after dinner but invariably they shared the pride in their spouse's accomplishments." Even at Parent-Teacher Association meetings, he recalled, wives would help lobby their husbands' supervisors for increased project funds. "Perhaps this way of conducting business was the result of serving alcoholic beverages at the meetings, something entirely unique to the China Lake PTA."[29]

Party in Hugo Meneghelli's back yard, early 1950s.

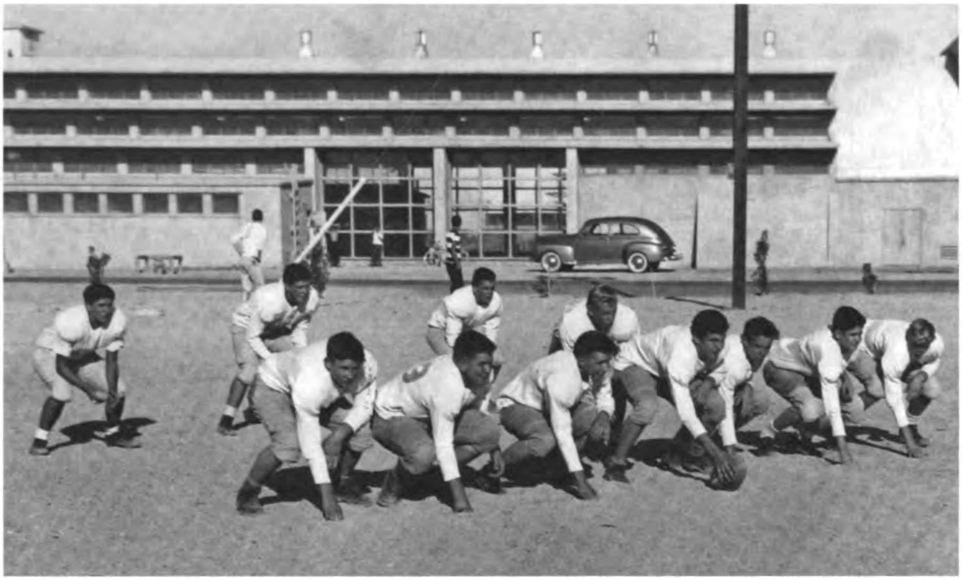
Emory Ellis (cigarette in mouth) is in the background and Levering Smith is seated at right.

Ellis scrapbook, China Lake archives

Most employees had been recruited as they were starting careers, and the community was a young one. Tina Knemeyer remembered her four-year-old daughter raptly observing a sea of gray heads at a church service in Glendale, then asking why so many grandmothers were there. She had never seen that many old people in one place before. "When I had my first scout troop, we had to hunt for an old lady so that the kids knew what to take across the street," said Eleanor Lotee.[30]

In young China Lake, an easy camaraderie among Navy and civilian families contributed much to community life. "We worked hard, we played hard, we shopped together, we went to church together, and our whole lives were just intertwined," said Polly Nicol.[31] Professional, fraternal, and hobby organizations of an astonishing number and variety flourished, often in clubhouses maintained by a command determined to provide amenities to keep employees and their families happy. "When we got some new people and they had a new idea, we just started a new club," recalled LaV McLean, wife of the station's third technical director. "At one time, I remember about 200 clubs like the Gem and Mineral Club, the Rockhounds and square dancing . . . . It only took a few members to start a club. And it was so easy for us because we all lived so close."[32]

Sports events were favorite community activities, with softball, baseball, bowling, football, and boxing vying for the attention of the fans, who were a determined lot. When 1,200 hardy souls turned out to witness an outdoor professional wrestling exhibition, the show went on despite gale-force winds.[33]



Courtesy Historical Society of the Upper Mojave Desert, Bette and Larry Fox collection

NOTS football team outside the station gymnasium, 1948.

Courtesy Maturango Museum

Opening day of the Officers Club outdoor pool, 24 September 1950.

The community, led by LaV McLean, raised funds for the pool and constructed it with donated materials and volunteer labor.

The Navy messes—the military clubs—were the center of social life for the entire community. The Commissioned Officers Mess, referred to as the "O Club" or just "the Club," had been going strong since 1945. In October 1948 the club officially became an open mess, allowing membership for civilian employees in grades comparable to the ranks of the military members.

In a letter of support for the open mess, BuOrd Chief Noble commented, "The success of the classified programs assigned this station depends in large measure on ability to attract and hold civilian scientists of the best type. Equality of privileges in an open mess would make such employment more attractive to the civilians living on the station." Good recreational facilities at China Lake were advantageous for security considerations in that residents "will not desire to leave that station to satisfy their gregariousness."[34]

Rubbing shoulders at the O Club also helped turn military and civilian teammates into friends.

Like the O Club, the Chief Petty Officers Mess offered dancing, drinking, dining, and conviviality. The Chiefs Club had started in late 1945 in a couple of Quonset huts at Harvey Field in Inyokern. As the station's main activities moved to China Lake, the chiefs obtained permission to move the huts to a new location across the street from the China Lake fire station. Through volunteer labor, after-hours use of NOTS equipment, and favors collected, the chiefs were able to pour a large slab and begin modifying the huts to fit their new location. According to Chief George Hucek, who had come to NOTS as a member of the station's first explosive-ordnance disposal team in 1944, the chiefs made one big change:

> [W]e'd taken those old huts and instead of putting them up with a 20-foot radius, we moved them out to 40, and the idea is when they come up here,

Ellis scrapbook, China Lake archives

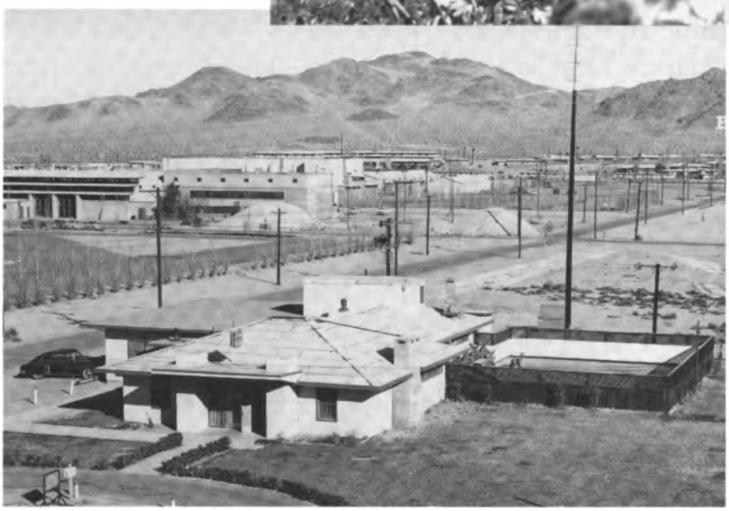
"Cats" ready for a Halloween party at the Officers Club.

From left are Paul Longwell, Marion Ellis, two unidentified cats, Levering Smith, Ovita and Fred Brown, Boots Smith, Liz Robinson, Edith Longwell, and Ken Robinson.


China Lake archives

Awards banquet at the Chief Petty Officers Mess, 1952.

Seated in front are Polly Nicol (left) and Jeanne Schreiber. Behind them Leroy L. Doig, Jr., (right) shakes hands with an unidentified man. Standing in back (from left) are Amos "Steve" Etheredge, Peter Nicol, Maurice Coleman, and J. Raymond "Ray" Schreiber.


U.S. Navy photo NP/45 54664

Chief Petty Officers Mess (later Command Conference Center), January 1953.

Behind the club building is the station gymnasium.

> we're going to put props across there and then tie them across the top, and that would make it larger. The only thing is we outsmarted ourselves. The wind came up and blew them all over into the swimming pool.

As the chiefs fished sheet metal out of the water, they decided to rethink their construction plans. Somebody mentioned a pile of used lumber stashed behind the O Club, and somebody else remembered seeing cartons of rock wool stacked beside the base steam plant. The chiefs "liberated" these and other materials to construct a building that opened with appropriate ceremony on 11 September 1948 as the first Chiefs Club in China Lake. The new clubhouse was on the modest side, but it served its purpose.[35]

In the station's early days, slot machines drew gambling enthusiasts to both clubs. In 1951, however, after an act of Congress prohibited slot machines on federal premises, China Lake's popular one-armed bandits were taken to the dump, where a bulldozer smashed them beyond all possibility of repair. Budget adjustments became necessary, since users of the machines had added substantially to club coffers.[36]

As Noble hoped, on-station amenities did satisfy the gregariousness of many, but remnants of the boisterous wartime days remained in the night life of the area surrounding the station. The Goat Ranch on the outskirts of Lone Pine, Big Bertha's in Bishop, and the Desert Lodge (also known as "The Y") on the way to Trona were among the bordellos declared "Out of Bounds" for naval personnel. Rumor had it that interested civilians found the "Out of Bounds" memos useful advertisements for the forbidden establishments.[37]

China Lake archives

China Lakers at slot-machine-equipped Officers Club, circa 1948.

Among those seated at the bar are Dr. Pauline Rolf (second from left) and Paul S. Flahive (center, in plaid shirt). Standing are (from left) Dr. John W. Odle, unidentified, Dr. Ivar E. Highberg, and Maurice S. Clifton. At far right is George E. "Eddie" Barsell, original owner of the photo, and just to his left is Rick Feinstein.

Cultural Activities

The China Lake community also participated avidly in cultural activities, with plays, concerts, and other public diversions invariably drawing large audiences. In 1948 the NOTS Concert Series, operated by a committee of the Navy-Civilian Recreation Council, was just in its second season—a glorious one, featuring famed ballerina Mia Slavenska and her Ballet Variante, the Vienna Boys Choir, the Pasadena Civic Orchestra, and internationally renowned pianist Arthur Rubinstein.[38] Kenneth H. Robinson, an early force behind the success of the series, was able to book this and subsequent seasons through the West Coast booking agent for the Sol Hurok Organization.

When season tickets at $8 each went on sale in the station's work areas, the entertainment-hungry community snapped up all 1,200 tickets.[39] Station management smiled on the sale of concert tickets in the workplace, and consequently, as Bruce Wertenberger recalled, he was able to use "a technique that I'm sure would not be acceptable now" to achieve the status of star salesman:

> I simply went to Personnel and asked for a list of all the JPs [junior professionals] that had hired on the previous year. I thought that since they would be used to going to concerts during their college days, that they might like to continue that. Well, I sold quite a few.[40]

U.S. Navy photo NP/45 22568

Front entrance of the Station Theater, July 1949.

Rubinstein, a favorite of that second season, returned to great acclaim in 1952, when the *Rocketeer* reported that he "reflected warm appreciation of his audience's unstinted applause, responding with generous encores." Artists performing in China Lake frequently expressed their amazement at finding a well-equipped 1,300-seat auditorium in a remote, obscure location. Yehudi Menuhin, for example, was pleasantly surprised to find that, contrary to his original surmise, he would be playing his repertoire in an auditorium for a large, knowledgeable audience rather than in a dinner recital for some wealthy sheepherder.[41]

Performances in the Station Theater differed from those in more metropolitan areas in several respects, though. For one thing, the auditorium had been designed for films and all-hands briefings, and the volunteers helping set up for the concerts frequently had to use all their engineering ingenuity to accommodate for nearly nonexistent stage wings and aprons. For another, the uniformed ushers were the same sailors who normally patrolled the aisles during movie showings. Lois Allan recalled:

> I've forgotten what the concert was, but at any rate it was classical music. Everybody was sitting there decorously and quietly, and these two sailors came walking down the aisle, looking around at everybody, and came backstage at intermission and said, 'Well, Mr. Robinson, we're glad to report there were no disturbances out there tonight,' and Ken said, 'Son, I've got news for you. *You* were the only disturbance.'[42]

Much of the concert series' success could be attributed to the extraordinarily high quality of the programs. But China Lakers also had a seemingly insatiable appetite for less polished homegrown divertissements.

In celebration of the 1948 Christmas season, for example, WACOM and the Navy-Civilian Recreation Council sponsored a play entitled "Why the Chimes Rang," presented to a capacity crowd in the Station Theater, enhanced by scenery constructed and painted in Public Works shops, and including in the cast the wives of both commanding officer and technical director.[43]

Desert Stewardship

As the community flourished, China Lakers with a bent for the natural sciences worked to preserve remnants of what the valley was like before the Navy arrived. The station housed the China Lake Museum of Natural Science in a prefabricated building tucked away in a corner of the old Burroughs High School grounds. This modest one-room museum celebrated the desert's natural and cultural history year-round, with displays of birds' eggs, mineral

Pleistocene-era relics, and artifacts from former cultures of the Northern Mojave Desert. The museum was established in 1947 as a place to display a huge mammoth tusk, 9 feet long and more than 15,000 years old, that a NOTS bulldozer uncovered near the southeast end of the China Lake playa.[44] Darwin Tiemann, a station employee with a passionate interest in desert flora and fauna, became the new museum's first curator. At his urging, the China Lake Natural Science Club was formed in November 1948 to support the museum and "to extend its scope and make it a permanent cultural asset for the community."[45]

The little museum soon became a conservator of important prehistoric relics. In 1947 local sportsmen Duane Mack, Paul Flahive, Jules "Buddy" Deffes, Ed Barcell, L. Ely, and Sam Wyatt (all NOTS employees) had discovered an ancient skeleton and a treasure-trove of hunting and gathering tools in a cave near Little Lake, just outside the station's western boundary. The men removed the skeleton and several of the more remarkable artifacts to Armitage Field, where the impromptu display reposed in a dusty glass bookcase until sometime in 1948, when Mack asked Tiemann if the museum would like to have the artifacts. Tiemann immediately recognized the significance of these remnants of an ancient civilization. He turned them over to Mark R. Harrington, curator of the Southwest Museum in Highland Park, California, who coincidentally was in the midst of a significant archaeological exploration of an area that encompassed the cave where the hunters had found the skeleton.

When the artifacts were still in the airfield bookcase, Willy Stahl, an enthusiastic amateur archaeologist from the Los Angeles area, had independently discovered the cave site. At Harrington's suggestion Stahl had been exploring the lower end of Owens Valley on a quest for interesting archeological sites within a day's commute of Los Angeles. In March 1948 Harrington set up camp at the mouth of the cave and began careful excavations of what he named the Stahl Site. Over the next three years, Harrington and his staff, assisted by Stahl and UCLA archaeology students, found several house sites and numerous tools and obsidian arrowheads scattered nearby. Grass and bark implements, as well as tree holes found in the hardpan beneath the remains, convinced the investigators that members of the Pinto culture, an early Shoshonean civilization, had lived there in a lush, forest-covered terrain between 3,000 and 4,000 years earlier.[46]

Other early monuments to man's presence on the desert were the hundreds of petroglyphs, the largest concentrated collection of rock art in North America, pecked and chipped into the basalt walls of Petroglyph and Renegade Canyons

Courtesy Ridgecrest Chamber of Commerce

Ancient rock art at Little Petroglyph Canyon.

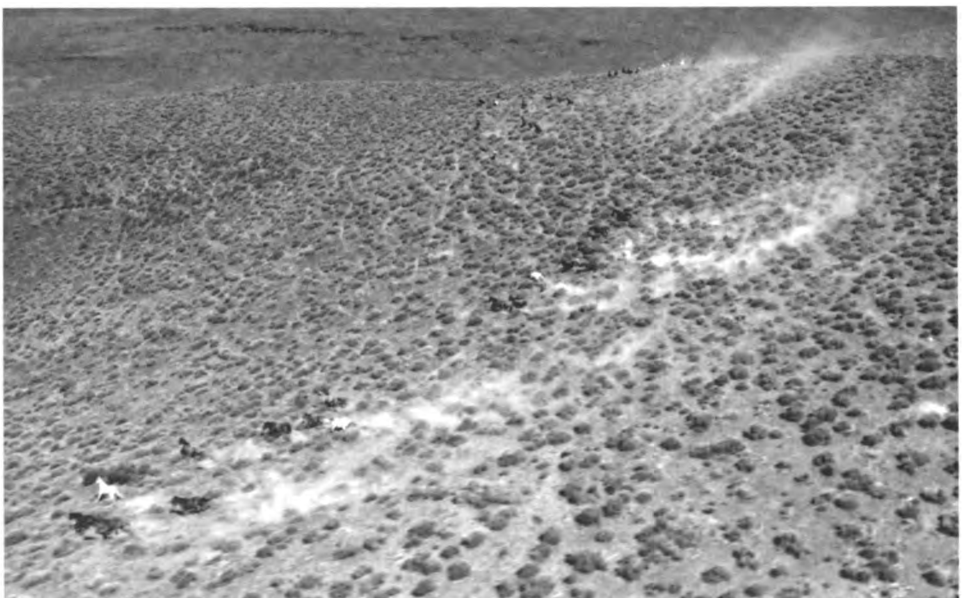
(now called Big and Little Petroglyph Canyons) and other canyons in the remote Coso Range within the confines of NOTS. During the station's early years, few people were able to see these excellent examples of aboriginal art because the Navy required special arrangements for weekend permits to avoid interfering with firing schedules. With the 1948 formation of the China Lake Natural Science Club, the logistics of public access became somewhat easier, since the club could arrange for permits and coordinate occasional group visits to the area.[47]

In addition to exercising responsible stewardship over the remnants of earlier civilizations, station commanders had a responsibility to safeguard the flora and fauna in China Lake's vast backyard. The NOTS conservation program officially began in the fall of 1956, but more limited conservation efforts began much earlier.[48] In 1953 NOTS closed its ranges to hunting, and station officials began cooperating with the California Fish and Game Department to manage the population of chukars, small, docile wildfowl imported from India and planted in the Indian Wells Valley area by California wildlife officials in 1933. Chukars had adapted so well to the Mojave Desert that they experienced a survival rate of nearly 100 percent. State game wardens entered the ranges annually to trap the birds—about 450 each year between 1953 and 1956—and transport them to nearby hunting areas for the benefit of local sportsmen.[49]

Complicating the station's desert stewardship was the need to deal with conditions predating the Navy's arrival on the desert. Canny feral burros, for example, were descendants of hardy pack animals brought west with the missionaries and later used by prospectors. The Navy's worst problems with herds of burros were still in the future, but conservationists were already concerned that these inquisitive, intelligent animals were encroaching on the hardscrabble existence of other desert wildlife.[50]

Herds of wild horses also flourished on NOTS ranges. After the end of World War II and on into the early 1950s, miners who had vacated their claims when the Navy came to the Indian Wells Valley petitioned authorities in the Navy, the State of California, and Congress for the return of free-roaming horses that the miners claimed as their property. The NOTS Legal Office set up procedures protected Navy land holdings from inappropriate entry but still allowed legitimate owners to enter the ranges and remove their animals.[51]

The seasonal availability of pasturage and water also made the desert a desirable place for ranchers from Kern River and Owens Valleys to turn their cattle loose during the winter. Huge herds of up to 5,000 cattle that had run in the Mountain Springs Canyon area during the early 1900s no longer existed, but leases administered through the Bureau of Land Management still allowed cattle to roam over nearly 40 percent of the station's land holdings, much of



U.S. Navy photo LHL 202349, courtesy John Di Pol

Wild horses running across a slope, China Lake north range.

Courtesy U.S. Naval Museum of Armament and Technology

Sailors installing a danger sign, a mile south of Seeburg Wells, Mojave B Range, September 1949.

this acreage in the southwest part of Mojave B Aerial Gunnery Range.[52] Mojave B, encompassing more than 300,000 acres of remote desert south of Death Valley, had been withdrawn for Navy use by agreement with the Department of the Interior in 1942. The Navy took over active administration of the range in 1947. Several thousand acres within Mojave B, however, were leased from private owners. Officials at NOTS responded by granting scheduled visits for "salting, maintenance and round-ups."[53]

The station asked the affected ranchers to waive damage claims "provided such damage is not willfully inflicted." In return, Navy test pilots using Mojave B Range were instructed to keep as much as possible to the uninhabited north and central portions of the range. When a scheduled test might affect the range areas, a pilot flew over and dropped two red smoke flares, one the day before the test and one just as the test was about to begin. In addition, pilots were encouraged to use "mild 'buzzing' tactics" to attract attention to the flares.[54] These procedures were workable enough when the range was used infrequently, but by 1948 an active gunnery training program made safety measures difficult. As grazing leases expired, they were not renewed.[55]

Several grazing permits still existed on both of the station's range complexes, however. Range guard Sewell "Pop" Lofinck kept an eye on herds not otherwise

Miner's cabin near Junction Ranch, China Lake north range.

tended between when they were driven onto NOTS ranges in early winter and when they were rounded up in the spring. He also frequently accompanied prospectors on trips to their former mining sites so that they could haul out equipment, and, at the request of the Legal Branch, he used his considerable negotiating skills and sensitivity to desert etiquette to help resolve miners' claims that were likely to be as eccentric as their claimants.[56]

The Law of Wild Horse Mesa

One of the most popular of the magnificent mavericks, Pop Lofinck was responsible from 1947 to 1962 for guarding the north ranges of the China Lake Complex, a vast and varied land of some 624 square miles. China Lakers affectionately and respectfully referred to Lofinck as "the Law of Wild Horse Mesa." Armed with a .357 Magnum, a .45 with a six-inch barrel, resonant vocal cords, and a mission to protect the desert he loved, he patrolled his domain in a dusty Navy jeep, traveling a distance he estimated at 800,000 miles during the 15 years of his isolated assignment.[57]

During his early years on the north rangeland, Pop had an assistant, Billy Ball, who became a range guard at about the age of 82. Ball was a longtime resident of Coso Hot Springs, a health resort established in 1914 to take advantage of the area's bubbling mud pots and hot mineral waters, remnants of volcanic activity in the rugged Coso Range. When the Navy arrived on the desert, Ball persuaded the spa's other residents to sell their houses as a patriotic duty. The station gave him the range-guard job partly in gratitude, partly to take advantage of his familiarity with the area, and perhaps partly to allow him to stay near the hot mud and medicinal water that he swore had brought him back to health after an accident years earlier. The healing water must have done the job; he reached the age of 101 before he died.

With or without an assistant, though, Lofinck had a big job. This 20th-century range rider developed a variety of tactics that allowed him to find interlopers in an area dotted with nearly 200 mines, as well as coyotes, wild horses, burros, and occasional herds of cattle. "Patrolling a wilderness area half the size of Rhode Island isn't as difficult as it might seem," he said, adding that he would sweep off existing tracks by dragging brush across the road at strategic points, then check later for fresh tracks. He also frequented high vantage points, scanning the desert through binoculars for telltale clouds of dust.

Lofinck was a voluble talker about desert lore, but reticent about his own vital statistics. He let slip at one time or another that he had been born in Manhattan, Kansas, toward the end of the 19th century and that he had job experience as a surveyor, examiner of mineral claims, real estate broker, aviation mechanic, and prospector. He came to the Indian Wells Valley to work a claim during the Great Depression and joined the NOTS work force in 1944 as the airfield motor-pool coordinator. He also worked briefly as a rocket materials inspector before he began his range-patrolling duties, which he described enthusiastically as "the most enjoyable job I ever had—and I got paid for it!"[58]

Courtesy Maturango Museum

Range guard Sewell "Pop" Lofinck.

His Junction Ranch headquarters had served as a way station in the 1870s and '80s for silver-bullion-laden wagons traveling through Renegade Canyon, then had housed a cattleman grazing his cattle on nearby rangelands. Junction Ranch was about 30 miles north of the China Lake community as the crow flies and about 40 miles by the road directly up Mountain Springs Canyon, but more like 110 miles by the circuitous highway route visitors had to take.

Lofinck lived on the ranch in a 50-year-old frame cabin, huddling by the stove for warmth on chilly winter nights. Early attempts to keep a field telephone working were foiled by the sharp hooves of the ubiquitous burros, whose curiosity motivated them to claw up the phone wires strung along the ground. Consequently, his only communication with the outside world was a radio transmitter. In 1950 the Public Works Department built a new five-room house and garage next door to the old ranch house, and Lofinck's living conditions became less Spartan.

It took a lot to drive him away from the desert he loved. When a heavy rainfall for the Indian Wells Valley in 1952 became 14 inches of snow at the higher elevation of Junction Ranch, he finally sought refuge in the China Lake housing area. But he left his home on the range only when water pipes at the ranch froze and the electric generator refused to work.[59]

He took justifiable pride in being "the Law of Wild Horse Mesa." But his role in China Lake's history was much richer than that. His abiding interest in the station's history and natural setting involved him in the NOTS Rockhounds and other community activities that furthered knowledge of the desert. He was also an active participant in the Navy's organized conservation efforts. His freely shared wisdom on travel in the desert undoubtedly saved lives, and his love of the desert rubbed off on those who had the privilege of traveling the dusty back roads of NOTS with him as their guide.[60]

Desert Mavericks

Life on the desert, then, had its rigors, but it also offered many riches—the opportunity to shape a community from the ground up, closeness to both work and the great outdoors, and most importantly the opportunity to work far from the restrictions that an overly watchful bureaucracy could have imposed. With the creators of the station's products and the users of those products living together as friends and neighbors, high morale and productivity were the results.

3

Pasadena Annex

At the close of World War II, when Caltech transferred its wartime rocket facilities and employees to the Navy, several facilities in the Pasadena area were part of the package. In 1948 the station took over direct operation of these facilities, gaining approximately 400 new employees in the process.

The work of the NOTS Pasadena Annex differed in significant ways from that of China Lake. While employees on the desert focused on aerial weaponry, those in Pasadena worked on undersea products and concepts, including design of torpedo components and research in water-entry ballistics and underwater propulsion. Although the work styles of Pasadena and China Lake were as disparate as their products, the two organizations generally blended well. The two sites shared a heritage from the World War II military-scientific partnership, and a spirit of cooperation and mutual trust existed among their leaders.

Welcome to Pasadena Employees

On 1 July 1948, with the end of a large three-year contract with General Tire and Rubber Company (GT&R), NOTS gained one of the largest groups of employees ever to enter station rolls in a single day. In a mass personnel action at an improvised outdoor arena adjacent to the Foothill Plant, 430 former GT&R employees stood to be sworn into Civil Service, thereby instantly doubling the number of NOTS employees in Pasadena.[1]

This influx of new annex employees was a planned step in a post-World War II effort by the California Institute of Technology to get out of the weapon-development business. In 1945 several facilities in the Pasadena vicinity, previously operated as part of Caltech's wartime rocket and torpedo work, had been transferred to NOTS to become the Pasadena Annex. The idea was that Caltech employees who wished to continue their wartime affiliation with the U.S. government would simply keep on working for NOTS and that the Pasadena site would thus make a smooth transition to the station's control. At war's end, though, when many Caltech people returned to academia, BuOrd

TS 59-200, Facilities Review, courtesy Howard Auld

Entrance to Pasadena Annex.

U.S. Navy photo NP/45/P/626

Green Street offices, Pasadena Annex.

realized that NOTS was not adequately staffed and equipped to handle the entire transfer package at once. As a result, the bureau accommodated a more gradual transfer by hiring GT&R to operate the facilities in Pasadena. Over the ensuing three years, while GT&R performed the administrative and technical services needed to keep the Pasadena operation working smoothly, NOTS gained the management depth it needed to assume the entire burden.[2]

Station leaders saw a small liaison and procurement unit in the metropolitan area as useful, but initial thinking had been to maintain a large Pasadena operation only until China Lake was adequately equipped and staffed. But the utility of a good-sized Pasadena Annex soon become evident. Pasadena could provide immediate access to industrial centers, and it offered specialized facilities and proximity to ocean operating areas. The Pasadena facilities were spread out among several sites on Green Street, on Foothill Boulevard, in Eaton Canyon, and at nearby Morris Dam.

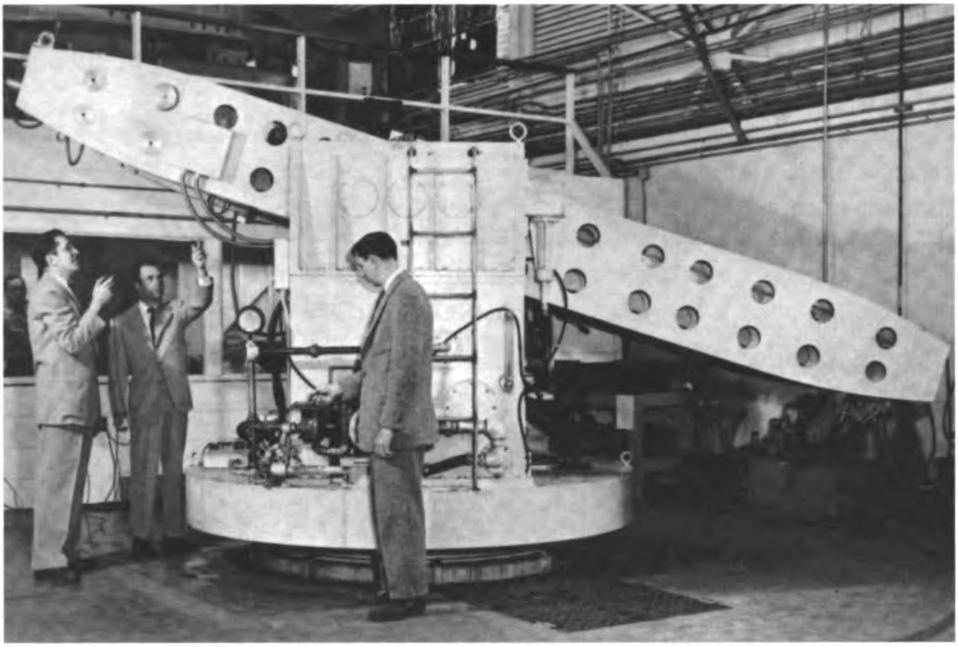
Headquarters, shops, and offices were at 1030 and 1070 East Green Street, a block south of Colorado Boulevard. Conveniently for NOTS, the Pasadena branch of the Office of Naval Research, responsible for coordinating all patents and Navy cases for the Eleventh Naval District, was also housed at Green Street.

Foothill Plant at 3202 E. Foothill Boulevard encompassed a series of warehouses, office spaces, laboratories, and machine shops so extensive that they doubled the station's shop capacity. A light-metals foundry gave the station the ability to produce aluminum and magnesium castings on development and pilot-production scales. A chemistry laboratory was used for work on torpedo fuels. A model laboratory allowed laboratory-scale work in water-entry phenomena and underwater ballistics. Construction of the newest Foothill facility, the Hydrodynamic Simulator, was finished just a month before GT&R turned the annex over to NOTS. Pasadena scientists used the simulator to subject full-scale torpedoes to conditions simulating those encountered in sea runs.

As the first computers became available, the annex acquired a Reeves Electronic Analog Computer (REAC) to collect data that would allow analysis

U.S. Navy photo LHL-P 1533 courtesy Jim Campbell

Foothill Plant, 13 April 1951.


TS 59-200, Facilities Review, courtesy Howard Auld

Hydrodynamic Simulator for torpedo environmental testing.

of torpedo characteristics and guidance and control problems. Used in tandem with the Hydrodynamic Simulator, the new computer allowed Pasadena scientists to estimate the hydrodynamic effects of deviation, pitch, depth, and roll with new sophistication.[3] Former Caltech assets included rocket-firing and explosive-research facilities at Eaton Canyon, the first site of the university's wartime pilot plant, in the foothills of the San Gabriel Mountains.

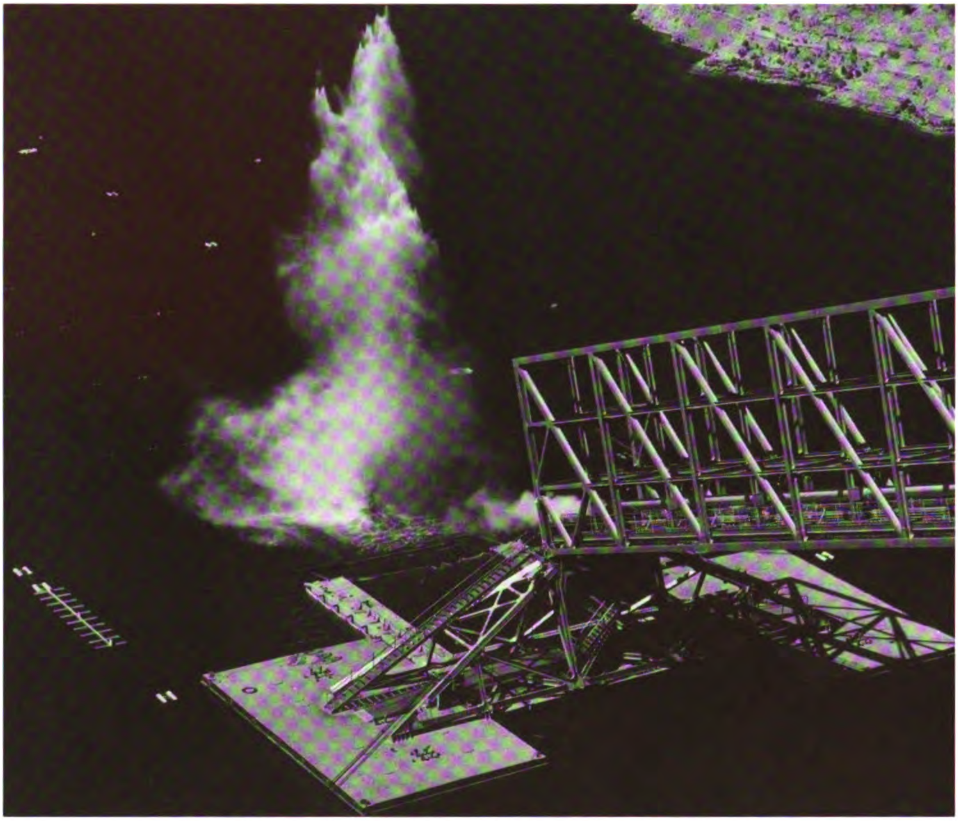
Morris Dam was a convenient 20 miles east of Pasadena in the Sierra Madre Mountains. Here the waters of the San Gabriel River formed an eight-mile-long lake, leased by the Navy from the Metropolitan Water District of Southern California. The City of Pasadena owned the dam that made the lake deep enough to accommodate the station's water-entry and underwater-trajectory studies. Morris Dam was home to an underwater cableway and instrumented facilities used to help test the strong, streamlined projectile shapes necessary for water entry and underwater operation. The Fixed-Angle Launcher allowed full-scale torpedoes to be launched under controlled conditions, and the steeply rising mountains surrounding the lake provided excellent camera sites.

Pasadena employees found these facilities useful for testing water entry of torpedoes, depth bombs, and components, as well as for experimenting with new chemical fuels, high-energy batteries, prime movers, and thrust-producing mechanisms. "Controlled experimentation was what we did there," said one employee. "We could put a device on the cableway and let it swim down the cable. You could measure certain characteristics because the device location was known. It couldn't get away from you because it was on the cable."[4] One of the site's most innovative facilities was a slingshot launcher employing what were basically huge bungee cords to fling large projectiles into the water from as high as 160 feet in the air.

The largest improvement at Morris Dam was the ingenious Variable-Angle Launcher (VAL), designed and managed by members of the Underwater Ordnance Division (a Pasadena component of the station's Aviation Ordnance and Test Department), financed largely through unexpended construction

U.S. Navy photo

Morris Dam and reservoir.



Variable-Angle Launcher at Morris Dam, 30 April 1948.

funds remaining in a GT&R contract of World War II, and dedicated on 7 May 1948, just a day before the dedication of China Lake's Michelson Laboratory.[5] An all-welded steel bridge 22 feet wide, 35 feet high, and 300 feet long, the VAL supported two launching tubes from which torpedoes and other full-scale projectiles could be launched at various angles and at velocities of up to 1,000 feet per second. Arrays of cameras and hydrophones recorded test trajectories. Navy divers recovered items under test from the murky lake bottom.[6]

As the time came for employees at Pasadena to become an official part of NOTS, *Rocketeer* Editor Erma Pierson wrote in a welcoming column, "It is going to be something to learn, this saying 'NOTS' and meaning the personnel at the Pasadena Area too."[7]

Station leaders knew well that melding China Lake and Pasadena into one NOTS family would be something to learn. Nearly 150 miles separated the two locations. Only a few telephone lines linked the organizations, and getting through on the phone could take half a day or more.[8] A more subtle separation occurred through differences in lifestyles. For China Lakers tolerating the harshness and isolation of their physical setting was a matter of esprit de corps. The close desert community of scientists and engineers, whose vocations were also their avocations, enjoyed a virtually seamless blend of work time and leisure hours. "People could and did communicate with each other all day, through the cocktail hour, and for as long as the parties lasted at night," said Dr. William B. McLean. "The isolation in a location where the job could be performed provided large measures of the intimate communication which is so essential for getting any major job completed."[9] Most Pasadena employees were also dedicated to their careers, but the Pasadena Annex was an enjoyable place to work—not a way of life. Neighbors were not often co-workers, and the ready-made leisure-time pursuits of the metropolitan area diminished enthusiasm for after-hours employee get-togethers.

Annex employees would have to adjust, too, to a more direct relationship with the Navy. According to Pasadena old-timers, Akron-based GT&R was a good company, forcefully managed by Trevor Gardner, vice president in charge of California operations. Gardner's ties with NOTS and Caltech later served the station well when as Air Force Special Assistant for R&D he played an important role in Air Force acceptance of the Sidewinder missile. But in the early days of the contract, Gardner sometimes gave Caltech employees waiting to transfer to civil service the impression that "he thought that the Navy was working for General Tire and Rubber."[10]

James H. "Jim" Jennison, who entered civil service in October 1945 as chief engineer for the VAL, spoke for many of his peers at Pasadena when he observed:

> Many of us recognized that there were some benefits to being attached to the larger Center at China Lake but there were also many restrictions that we did not like. We felt that the people at China Lake didn't understand our problems, our needs, and I guess this was true at times. We often thought that their viewpoint, their attitude was that they shouldn't let us be too successful or we might secede from the union, and we had thoughts of doing that.

Jennison and others also realized, however, that on balance the benefits of being part of a larger organization led by individuals who could provide strong advocacy in Washington generally outweighed the drawback of having to operate under China Lake's managerial control.[11]

New Organizational Arrangements

Thompson and Switzer were eager to foster ties between Pasadena and China Lake, but they also knew that the most practical way to run the Pasadena site was to allow it as much autonomy as possible. Principles of operation for the Pasadena Annex, added to the Station's operating principles in February 1948, spelled out the organizational arrangements. The officer-in-charge (O-in-C) of the annex was designated the NOTS commanding officer's official representative in the Pasadena area and given responsibility for "the separate units of the Pasadena Annex as necessary to insure adequately integrated relationships among these units and with U.S.N.O.T.S." The Pasadena O-in-C also had responsibility for annex administrative activities, to be conducted through the military chain of command.[12]

When Pasadena employees joined NOTS, the O-in-C was Commander H. D. "Dale" Hilton, an experienced aviator who received his wings in 1937. During the early part of World War II, Hilton served in Air Group 6 aboard *USS Enterprise* (CV-6). After his aircraft was shot down by antiaircraft fire at Minami Torshima, he spent the rest of the war in a Japanese internment camp. His job at NOTS soon expanded to encompass responsibility for the civilians transferring to civil service from GT&R, and he began making weekly trips to the desert to confer with Switzer about the more frequent personnel-management problems that came with his new civilian contingent.[13]

In July 1948 Hilton left Pasadena for duty in Patrol Squadron Twenty, and Commander (later Captain) William A. "Red" Hasler moved up a notch from Deputy O-in-C to assume command at the annex. An Academy graduate, Hasler had a highly suitable background, including wartime service as a gunnery officer and ordnance training from the Massachusetts Institute of Technology. The good-natured officer was popular from the first with civilians, who remembered him as "like a civilian at heart."[14]

Just as for China Lake, responsibility for assignment of tasks "to the several technical activities in the Pasadena Area" rested with the technical director and the Research Board. The principles also contained provisions for a technical coordinator, a civilian leader who would serve as the technical director's Pasadena representative. On paper the technical coordinator exercised no administrative authority over annex technical work except as delegated by the technical director. In reality the coordinator often operated autonomously.

William H. Saylor, a Caltech graduate in engineering who had been a NOTS employee since 1945, had served capably at Pasadena from 1945–1947 as technical coordinator for NOTS and head of the Underwater Ordnance Section. When Saylor moved at Thompson's instigation to a developmental assignment as assistant head of the Experimental Operations Department at China Lake, John L. Cox, another Caltech alumnus hired

William H. Saylor, June 1951.

at NOTS in 1945, took over the technical coordination duties in June 1948 in addition to his regular job as head of the Development Engineering Section of the Underwater Ordnance Division.

Early stages of the Caltech transfer of Pasadena facilities and projects to NOTS caused a few problems and misunderstandings. By 1948, however, much of the friction was gone. Annex employees complained that the station's leaders did not spend enough time in Pasadena, but the earlier fears that rambunctious China Lakers would try to change the annex way of doing business had largely dissipated.[15]

Space was a continuing concern, especially at the Foothill Plant, the interior of which resembled "a bunch of rabbit warrens."[16] A related concern was the question of whether facilities and disciplines should be duplicated at the two locations. The Research Board decided that the underwater work should be centralized in Pasadena, which had the technical expertise for that work as well as proximity to underwater testing facilities.

Other location questions were more perplexing. Should the new Design and Production Department, established a mere six months after discontinuation of the GT&R contract, be centralized at Pasadena, close to contractors and sources of supply, or at China Lake, convenient to most of the work? Should the prime location of the Physics Division of the Research Department be at China Lake, where the results of research were most likely to be applied, or at Pasadena, where more frequent interaction with peers in industry and academia was possible? Should Pasadena have its own autonomous shops, or should the shops at the annex be under the China Lake organizational umbrella?

Members of the Research Board heatedly debated this last question in an April 1948 meeting. Most members protested a command decision to establish the shops in Pasadena as a separate organization reporting directly to the Pasadena O-in-C. They reasoned that the "technical organization should be in a position to direct and control those activities upon which they intimately depend to accomplish their mission" and complained that "segregation" of the shop in Pasadena "indicates an undesirable tendency for the Pasadena Annex to become a separate organization from the Inyokern Station." The Research Board reached a consensus that it "did not believe that this action was to the best interest of the Station."[17] Hilton argued vigorously that all service operations at the annex should stay under O-in-C authority. Experimental officer Hean, who agreed with the majority, was eventually able to talk Hilton into going along with the decision.[18]

A decision to assign much of the station's production engineering activity to the Foothill Plant was swayed by BuOrd production authorities, who expressed preference for the Pasadena location under the rationale that NOTS employees located near the industrial firms doing the work were likely to be more "production-conscious" than were the more isolated engineers on the desert.[19]

Thompson and the Research Board concurred, but one key civilian leader was becoming increasingly uncomfortable with the important role the station's military leaders had in making those decisions. Dr. James H. Wayland, head of the Underwater Ordnance Division since January 1948, was a Caltech iconoclast, world-renowned in the field of underwater ballistics. He believed fervently in civilian management of R&D and was not hesitant about expressing his opinion that the military had entirely too much say in the day-to-day operations of NOTS.[20]

Despite Thompson's plea for understanding, Wayland turned in his resignation to return to Caltech as an associate professor in applied mathematics. Thompson asked Saylor to go back to Pasadena to fill this key civilian job, with Jennison his chief lieutenant.[21] The division became a department in 1949, with Saylor remaining UOD head until July 1950, when he became NOTS associate director for engineering.

Although Thompson had tried mightily to keep Wayland at NOTS, China Lake and Pasadena management relationships appear to have eased with the brilliant academician's return to his natural environment. Thompson and Saylor worked so well together, Jennison remembered, that their interactions had an almost mechanical smoothness. The slim, bespectacled Saylor not only served as the main link between the annex and China Lake, but also traveled frequently to Washington where he excelled at obtaining funding for Pasadena's underwater programs.

"Really, the day-to-day operations were under my jurisdiction, and he took care of the outside contacts and the political problems," Jennison said, recalling that Saylor "really did a lot to keep the organization on top of the problems that arose."[22]

Work at the Annex

True to the terms of the GT&R contract, most of Pasadena's postwar work focused on identifying what needed to be done to improve the Navy's lightweight torpedoes and on providing the facilities and theoretical base necessary to make those improvements. The early postwar emphasis was on basic research on the characteristics of the ocean medium as well as on torpedo components, with studies in ballistics, structures, controls, and propulsion systems resulting in important improvements in torpedo technology. Pasadena employees created new head shapes, fabrication methods, and propulsion fuels (including an innovative mixture of molten lithium and free seawater). Of particular note were two torpedo propulsion systems—a pumpjet and a hydroturbojet—used in the Mk 40 and Mk 41 torpedoes. Evaluation and troubleshooting on complete torpedoes also went on, notably on the Mk 32, an active-homing torpedo for use against deep-running submarines and the Mk 42, a deep-depth torpedo designed to be surface launched.

After the Pasadena Annex officially became part of NOTS, the main emphasis of annex work shifted from water-entry ballistics to studies of the behavior of weapons traveling through the air and into the water. Pasadena workers looked at nose shapes, control systems, and torpedo structures and accomplished pioneering work on cast aluminum bodies for torpedoes.

Saylor reported to the NOTS Advisory Board in August 1949 that UOD had the potential to revolutionize underwater ordnance, but not "the available manpower to undertake a complete development program such as would be required, without severely curtailing the basic research work which has just proved itself so invaluable." The board agreed that a more hardware-oriented approach was necessary.[23]

UOD employees often worked on teams with engineers from industry or other laboratories. For example, when the propulsion unit developed by General Electric Company for the Mk 41 torpedo was too noisy, BuOrd established a task with NOTS Pasadena for a quieter axial-flow pump system. Westinghouse also needed a similar system for its Mk 37 torpedo, and the Pasadena Annex obliged with a new pump system and simulator tests on the control system.[24]

The Design and Production Department, established in 1949, worked to ensure that preliminary designs for rockets, torpedoes, and guided missiles were adaptable to manufacture. Employees in the experimental machine shops, pattern shops, and foundry at the Foothill Plant devised simplified methods of manufacture to save time and money, a type of work that was also becoming

Foothill Plant Machine Shop, 11 February 1952.

increasingly important at China Lake. Experiments with lightweight metals and plastics resulted in new and improved ordnance components. Other experiments allowed intricate machined parts to be replaced by castings.[25]

Another asset binding the Pasadena Annex to its parent organization was a small procurement staff that not only obtained necessary materials and supplies for the Pasadena operation but also made it possible for China Lakers shopping for necessary items in the Los Angeles Basin to avoid going home empty handed. "I used to go down to L.A. with a circuit diagram and go to the electronics parts houses and find out whether they had the pieces I needed," said Richard V. "Dick" Boyd, who started his NOTS career in 1951 as an engineering aide. "If they didn't have the pieces I'd need, I'd redesign the circuit on the parts counter to make it work with the pieces that they had." He would then work through the Pasadena procurement representative to obtain the item he needed so that he could carry the item home to the desert on the same trip—a distinct advantage in an era of slow, erratic mail delivery.[26]

Physics Division Relocation

Thompson, who worried that the Underwater Ordnance Department had limited access to the in-house resources at China Lake, saw the Pasadena location of the Physics Division and several smaller Research Department organizations as making things more equitable. He also perceived an advantage for China Lake in the arrangement, since NOTS researchers in Pasadena could serve as communication links between their peers on the desert and Caltech and other important technical organizations in the Los Angeles area, as well as with the West Coast branch office of ONR.[27]

While an Applied Science Division at China Lake pursued research in aerophysics, optics, metallurgy, and mechanics, the Pasadena research staff worked on investigations of underwater phenomena, shaped-charge design, blast and shock wave theory, ballistics of ultra-high-speed particles, development of specialized underwater devices, initiation and detonation of explosives, spectroscopy research, and research on the physics of the upper atmosphere. Although much of this work involved areas of direct interest to China Lake projects, a tight housing situation at China Lake was a good argument to leave the organization in Pasadena.[28]

Then came an October 1949 reduction-in-force (RIF), part of a larger cutback, described by Rear Admiral Wilder D. Baker, Commandant Eleventh Naval District, as "a swing of the pendulum," with an eastward swing sending ships and activities back to the East Coast that had been brought west in the 1920s.[29]

The NOTS Administrative Board debated the pros and cons of several RIF alternatives, including two that would close the Green Street building and move more of the Pasadena work to China Lake. Switzer, mere days away from relinquishing station command, agreed to follow the alternative most board members favored, an option that would cut primarily nontechnical positions at both Pasadena and China Lake. Two weeks later, however, Commander Jack Monroe, NOTS experimental officer, returned from a BuOrd planning conference to report that Bureau Chief Noble had approved the station's RIF plan, but had also directed that Green Street be "closed at our convenience."[30]

The guidance from Noble changed matters considerably, and subsequent RIF plans took into account the goal of vacating the offices and shops at Green Street. Once dust from the RIF had settled, positions at China Lake were virtually intact and 200 employees at Pasadena had moved into new jobs. Although only one employee ended up walking out the door, the wholesale displacement broke up well-established work teams at Pasadena, many of them in place since the Caltech days.[31]

Thompson reluctantly agreed that moving the research group to China Lake made sense in light of the need to vacate the Green Street building. On 1 September 1950, the Physics Division, headed by Dr. Fred T. Rogers, Jr., was established at China Lake, with affected employees in the Pasadena organization offered transfers to the desert.[32] Rogers, who had come to the desert just the year before as a consultant on the Research Department staff, traded places with Dr. Roger S. Estey, with the Applied Science Division folded into the newly enlarged Physics Division and Estey becoming Research Department consultant. A few members of the Pasadena group, including the division head, Dr. W. M. Cady, opted to leave NOTS for other employment in the Pasadena area. Members of the Physics Division working primarily in underwater research transferred to UOD.

The organizational shake-up occurred with less bitterness than might be expected, according to Jim Campbell, one of the group remaining in Pasadena. Campbell said that he and many of the other affected employees thought the organizational move probably made good sense, since many Physics Division projects "had nothing to do with underwater ordnance."[33]

Annex Contributions

As mid-century approached, then, annex employees continued to make important contributions to materials research and underwater technology even as they adjusted to the organizational changes that came with closer ties to the mavericks on the desert. Creativity at the Pasadena Annex resulted in innovative facilities, new concepts in lightweight torpedoes, and new materials, notably protective coatings for aluminum to make it a suitable material for torpedo components. "I think our contributions really were significant in laying the groundwork for developments of later years," Jennison concluded.[34]

4

China Lake's First Missiles

The perception in Washington that NOTS China Lake should remain a rocket station made life difficult for NOTS and its supporters in BuOrd as the station entered the crowded guided-missile development field. Further complicating matters were political roadblocks erected largely as a result of disputes about roles and missions. These cognizance quarrels occurred among the three military services and between BuAer, which relied on industry to fulfill its specifications, and BuOrd, which preferred the full-spectrum productivity of its in-house laboratories. Station involvement in the fray often illustrated that military-civilian teamwork and a proactive approach can succeed spectacularly when support exists further up the management chain.

Station leaders had a tangible reason for needing the obstacles removed. After cancellation in 1949 of China Lake's first, short-lived, missile-development project, Dr. William B. McLean obtained in-house funding to begin testing his concept of a "heat homing rocket," an idea destined to become the Sidewinder missile.

Bill McLean—A Guiding Spirit at NOTS

Throughout his life, Bill McLean had a brook-no-obstacles, just-get-it-done attitude that those who worked with and for him at NOTS later referred to as "the China Lake way." Born in Portland, Oregon, in 1914, McLean was the oldest of three boys and the son of strong-minded, accomplished parents who exposed their children to a solid work ethic and continuing opportunities to stretch their minds. His mother, Clara Blohm McLean, taught her gifted son how to sew, a skill McLean gladly added to more traditional mechanical aptitudes. His father, Rev. Robert N. McLean, was a second-generation Presbyterian minister, an affable, articulate, and religious man who passed his own skills with tools along to his three sons.

From an early age Bill McLean knew how to build and fix just about anything. Gifts in the family were frequently tools, which he used to create electric motors and photographic equipment. He was adept at making do with the materials at hand, constructing, for example, a canoe from canvas and parts of an old touring-car top. He later concluded that his insistence on designing for simplicity and economy began as a result of "the tight purse strings he had to tug against in his youth."[1] Family frugality, however, ensured that Reverend McLean's modest income stretched far enough. Both parents encouraged their sons to pursue work that interested them. All three McLean boys later achieved advanced degrees and excelled in their chosen professions.[2]

After his 1931 graduation from Eagle Rock High School in Los Angeles, Bill McLean attended Caltech, where in the next eight years he earned bachelor's, master's, and doctoral degrees. An important influence was Dr. Charles C. Lauritsen, whose practice of stretching the Physics Department's budget by having his graduate assistants construct the needed laboratory equipment must have made McLean feel at home.[3]

During his senior year in undergraduate school, McLean discovered that he had diabetes, but he didn't let this condition slow him down, either then or throughout his life. In addition to carrying a demanding class load, he served as a part-time instructor in physics, worked in the photo lab, and built a half-million-volt Van de Graaff generator. He still had time for a social life, which began in 1935 to revolve around the charismatic personality known as LaV.

Arriving that year from Brookfield, Ohio, Edith LaVerne Jones entered Santa Barbara College of the University of California (now the University of

China Lake archives

Young Bill and LaV McLean, circa 1941.

California at Santa Barbara), where she majored in education. She became campus representative for the First Presbyterian Church of Santa Barbara under the direction of Reverend McLean. She soon met the pastor's shy, brilliant son, and the young people began a courtship that encompassed perching on the parsonage roof looking at stars with a telescope Bill McLean had made and surfing at Henry's Beach with big muslin surfboards he had designed and fabricated.[4]

Then in 1939 Clara McLean died suddenly and unexpectedly.[5] LaV had moved into the McLean household to help care for the two younger boys, and she recalled that after their mother's death, Reverend McLean suggested, "I think, Bill, you'd better marry LaV if you want to stay in the house." Bill and LaV McLean married that year, just two weeks after he received his Ph.D. The elder McLean then insisted that the young couple strike out on their own. Bill McLean accepted a job as a research associate with Dr. Alexander Ellett at the University of Iowa.

In Iowa City work with Ellett on nuclear reaction products gave McLean the intellectual stimulation he needed and the sort of practical challenge he loved, since he also had to design, construct, and modify the electronic equipment needed for his research. Then Ellett was called to Washington as part of the pre-World War II mobilization of science. McLean took over Ellett's classes and soon made a useful career discovery. "It was a good way that he learned that he wanted to do the research, but he just didn't like the teaching at all," LaV remembered.[6]

Meanwhile Ellett went to the National Bureau of Standards (NBS), where he became head of Division 4 of the Office of Scientific Research and Development. In summer 1941 Ellett invited McLean to join him at NBS, and the young McLeans happily set up housekeeping in an old house in Washington, D.C. Bill McLean immediately became engrossed in his work; LaV was busy taking care of babies and fostering a work-hard-play-hard lifestyle that foreshadowed the China Lake experience.[7]

McLean's first assignment at NBS was on a significant advance in military technology, the radio proximity (VT) fuze.[8] He later called this experience "the most valuable training which I have ever received." Throughout the rest of his career he applied lessons he learned on this project about designing for simplicity, producibility, and reliability.[9] His group of assistants grew into a section of about 40 people, and he became the head of the Ordnance Division's Mechanical Design Section. In 1943 he began work on a gyro-control system for the pioneering Bat missile. The plywood radar-guided Bat was carried under the belly of a Navy torpedo bomber. The first fully automatic guided weapon to be used successfully in combat, Bat was rushed to the Pacific theater in the final months of World War II, where land-based Navy patrol squadrons used it against Japanese ships and land targets. Other missiles would soon make Bat look awkward and unsophisticated, but for its day it offered a unique combination of self-guidance after release, long range, low angle of flight, and high payload.[10]

Bat missile, with workings exposed, on display at the U.S. Naval Museum of Armament and Technology.

A kindred spirit in McLean's gyro investigations was Jacob Rabinow, a resourceful inventor who rapidly became one of the handful of professional friends with whom McLean would exchange technical ideas throughout his life.[11] Rabinow had the bright idea of modifying a gyro used in aircraft to provide pilots with a vertical and horizontal reference. The modified gyro would allow a gimbal-mounted radar antenna to stay pointed at the target. Also needed was a way to provide the cumbersome Bat with pitch and roll control. To solve this problem Rabinow mounted a gyro on a steel ball and attached this apparatus to the shaft end of an electric motor. Although the gyro wheel would pick up speed when the motor ran, the gyro at first stayed fixed in its original direction and only slowly moved into alignment with the axis of the motor, so that, as Rabinow explained, the gyro "was not completely free of the shaft-and-ball mounting, but for short-duration motions, essentially free." McLean learned from Rabinow's ingenuity.[12]

The two men, who also worked on toss-bombing equipment for bombs and rockets, soon became frustrated with the lack of good testing space anywhere near Washington, D.C. Rabinow recalled that he and McLean fired a few rockets in a nearby grove of trees, but that one of the rockets was deflected by just one tree from a course toward the Hot Shoppe Restaurant on Connecticut Avenue.[13] McLean's search for a more suitable site coupled with timely recruiting efforts by L.T.E. Thompson led McLean to China Lake in spring 1945.[14] He liked what he saw—particularly the proximity of laboratory and test ranges—and by Independence Day, he was back on the desert, this time with his family.

He stayed on the NBS payroll until the following December, but China Lake had become home.

Missile by Committee

By the time McLean became a NOTS employee, he was already working on a mental picture of a weapon that would involve the Navy's remote desert lab in an extraordinary struggle. The question of which of the military services should be in charge of guided-missile programs was an aspect of a continuing quarrel that intensified when the airplane became a weapon platform. Naval aviators frequently trace the beginnings of this dispute to 1925 when the Army Air Service group headed by General William A. "Billy" Mitchell sought to take over control of all air forces.[15] The argument grew more heated after World War II, with the Air Force taking the position that strategic air power (long-range land-based Air Force bombers carrying atomic weapons) should be America's primary military capability. The Navy countered that carrier-based aircraft could accomplish the strategic bombing mission at least as well. Since guided missile programs were in their infancy at war's end, missile cognizance was not a significant concern at first. However, as missile programs grew so did the controversy.

During the postwar era, a series of U.S. missile-development programs began building on the advances of the German V-2 rocket. The new weapons were complex and expensive. Their capabilities could not be categorized under clear-cut service roles and missions. All U.S. missiles were ostensibly planned and coordinated within a National Guided Missiles Program, an organization that looked effective on paper. In reality, however, little role clarity existed among the various groups pursuing the more than a hundred U.S. missile projects started between 1945 and 1953.[16] Both the Truman and the Eisenhower administrations attempted to lessen conflict between the services and cut back on duplication by imposing additional coordinating authority over weapon programs. In an early effort of this type, the secretaries of War and the Navy established the Joint Research and Development Board (JRDB) in 1946 to coordinate all R&D activities of common interest to the services.

The JRDB was a small group, with two appointees from the War Department (the Army and the Army Air Forces) and two from the Navy. Dr. Vannevar Bush, the forceful, effective leader of the wartime Office of Scientific Research and Development (OSRD), chaired this new board. A series of committees and panels (including one on guided missiles) gave experts in the various scientific fields a systematic way to voice their opinions to the parent board. However, Bush soon discovered that, without budgetary authority, the JRDB had little real power.[17]

In a sweeping attempt to deal with interservice rivalries, the National Security Act of 1947 set up a National Military Establishment that encompassed all the military services; created a Secretary of Defense position with coordinating authority over the entire establishment; created the National Security Council; formalized the Joint Chiefs of Staff (JCS); and established the Air Force as a separate service. The act also replaced the JRDB with a more powerful Research and Development Board (RDB). The act and an implementing executive order by President Truman attempted to resolve cognizance disputes by assigning defense responsibilities among the three services roughly according to the maxim that "Armies walk, navies sail, and air forces fly." But new weapons under development since World War II could not be so conveniently compartmentalized, and James V. Forrestal, the nation's first Secretary of Defense, soon found himself a helpless pawn in a mighty struggle over cognizance—the dispute about which roles and missions each service should pursue.[18]

At first Forrestal hoped he could use provisions of the act and its enabling executive order to mediate among the services. The act stipulated that the secretary would serve as the principal advisor to the President in all matters of national security and would have responsibility for exercising "general direction and control." To these authorities was added a slightly more specific responsibility for R&D. The secretary was to take "appropriate steps" to eliminate "unnecessary duplication in research." With little real authority to enforce these vague responsibilities, Forrestal was bitterly disappointed to discover that rather than ending cognizance disputes, the reorganization became a catalyst for intensified debate.[19]

The new RDB, organized on 30 September 1947, had powers broader than those of its predecessor. The RDB was empowered to consider all military R&D matters and to advise the JCS on the interaction of research with national strategy. Again Vannevar Bush was the chairman and again the membership consisted of two representatives from each service. The RDB's fundamental objective, as stated in its charter, was coordination and integration of "the efforts of the Military Departments in seeking through research and development the best possible weapons and supporting systems for the armed forces of the United States, subject to limitations imposed by the availability of resources." R&D coordination would be accomplished through an overall plan, an important aspect of which would be elimination of undesirable duplication.[20]

Recommendations in specific technical areas came from some 15 specialized committees, with the committees in turn advised by a proliferating number of panels and subpanels. Members of these groups served part-time and came from the three services and the nation's academic and industrial communities. The peak of RDB activity involved more than 1,000 people, a number that grew from the board's attempts to authorize and coordinate programs at the project level. Students of RDB processes later pointed out that the committee and board experience gave many of the country's most illustrious scientists and engineering managers a valuable education in national security matters. However, the RDB had neither funding authority (reserved to Congress) nor power to direct or control the services' internal administration of their programs. Moreover, the board's recommendations were reached tortuously and often fit poorly into the overall plan.[21]

Despite these limitations, the involved organizations considered support from the RDB to be important, primarily because of the powerful connections of its individual members. The board also gave annual recommendations to the OSD comptroller for his use in marking up the defense budget. Furthermore, the board's insistence on formal reporting at the project level had a significant impact on the planning system of the Office of the Chief of Naval Operations. It was no coincidence that OPNAV's 15 planning objectives, broad statements of scientific or operational problems to be met by new equipment or scientific knowledge, conformed to 15 RDB "program categories."[22]

One of the first committees the RDB established (in late 1947) was a Committee on Guided Missiles (GMC). Bush was determined that the guided-missile development effort would be "a single coordinated program for all services without duplication or R&D gaps."[23] He had a challenge ahead of him, since the Air Force, the Army, the Navy Bureau of Aeronautics, and the Navy Bureau of Ordnance were all pursuing separate missile programs. Again, because of parochial interests among the GMC members, the committee did not tackle difficult policy decisions, but concentrated on reviewing the technical aspects of individual missile programs. And, as with the RDB, the services sometimes disregarded committee recommendations.[24]

From the NOTS perspective, the GMC and other RDB committees acted on the basis of information that was too general to allow for informed decisions. Station leaders also worried that the decisions suffered from an underrepresentation of members who understood the value of an in-house R&D effort.[25] The insider's view of RDB problems was well-expressed by Dr. Lawrence R. Hafstad in a 1949 talk to NOTS employees:

> The Research and Development Board is supposed to supervise, or scrutinize, all of the activities of the three departments and try as best it can to make sure that the really important urgent projects are well supported. . . . RDB collected all of the projects which were going on in the Military Establishment and turned up, when I was there, something like 18,000 different projects, and all of these projects—as near as we could tell from where we sat—were triple A-1 priority. . . . Now this is the difficulty of looking at this over-all national project from the topside. You people see it from the bottom side . . . and wonder why your projects can't be supported more effectively or more generously.[26]

NOTS would become all too familiar over the next few years with "topside" efforts to identify and eliminate what bureaucrats saw as undesirably duplicative programs—beginning with the station's first attempt to enter the guided-missile development business.

"That Isn't Your Job"

Nobody argued with the fact that China Lake's vast test ranges and clear desert air made NOTS a desirable site for testing guided missiles. The question of whether the station should design and develop its own missiles, however, was more controversial. As Thompson commented later, a "considerable element" within RDB "definitely felt for a period that there was something out of order in the station giving so much attention to development work. . . . that isn't your job and why don't you do your own job."[27] China Lakers yearned to apply their rocketeering expertise to the promising guided-missile field. In 1946 the station had proposed development of its first air-to-air guided missile, unglamorously titled "NOTS AM" (for air missile), "NOTS Interim Missile," or "Inyokern Air-to-Air Missile." BuOrd had given lukewarm authorization in March 1947 for a modest program without specific funding.[28] The station's Experimental Operations Department subsequently formulated plans for evaluation and engineering studies, which the bureau agreed to fund in January 1948. This authorization promised enough support that the NOTS Research Board set up a new Guided Missile Division, equal in scope to the Experimental Operations Department's well-established Underwater Ordnance and Aviation Ordnance divisions. Warner selected Dr. Andrew Vazsonyi, a native of Hungary with expertise in servomechanisms, to head this new Pasadena-based group, which as yet existed only on paper.

Thompson, concerned as always with thorough planning, added an ad hoc evaluation group to the new division. In the Aviation Ordnance Division, McLean had already started work on a seeker homing on infrared (IR) radiation, a concept that would evolve into the Sidewinder missile. Another idea, one the

Research Board accepted in 1948 as worth trying, was that an inexpensive weapon could be built rapidly with existing components and contractor assistance. At the close of World War II, General Tire and Rubber Company had inherited a small guided-missile organization from Jeep manufacturer Willys Overland. Now GT&R resources would be used to, in McLean's words, "take parts of the Sparrow and try to integrate them into an IR system."[29] In May 1948 GT&R submitted a report that described an air-to-air homing rocket and estimated that this weapon would be ready for fleet operational tests within two years.

BuOrd based its support for the station's first missile on the premise that a "combination of rocket propulsion techniques already developed and a simple infrared seeker, the basic principles of which are being developed on another project, may produce an urgently needed weapon in the minimum time."[30] That other project was McLean's early seeker work, which thus helped gain the day for the NOTS AM. The price was high: his efforts to foster progress by sharing his ideas with GT&R led in the 1960s and '70s to lengthy delays in obtaining clear patent rights to key innovations in the Sidewinder missile.[31] But in 1948 not a whiff of these later difficulties was in the air.

Although the bureau backed the NOTS AM, the program still encountered powerful opposition in Washington, particularly from the GMC. In May 1948 the Technical Evaluation Group (TEG) of the GMC sent a report to RDB questioning "the soundness of the philosophy behind this program" in view of other missiles already further along in the development cycle. "In this particular case, the additional question should be answered as to whether this work should be done in a governmental laboratory when competent industrial groups are available," the TEG report said, adding that one organization should not encompass both development and testing activities because developers had a vested interest in positive test results.[32] These views were directly counter to the NOTS philosophy that all aspects of RDT&E were best accomplished in one government laboratory.

The bureau answered TEG criticism with a memorandum of support for the NOTS AM in particular and for in-house laboratories in general. Government laboratories "must be used to the utmost and kept up to date . . . so that, in case of a national emergency when other contractors revert to more readily producible weapons and equipments, the government laboratories can continue the uncompleted developments," the bureau said.[33]

Only two days later BuOrd reinforced its vote of confidence by authorizing the first phases of a development program for which the station was given technical direction, along with a modest increase in funding. The station was "to achieve, in the shortest time practicable, detailed design and shop drawings of a prototype solid propellant rocket employing passive homing." Bureau authorities expected the new missile program to capitalize on NOTS' proven expertise in fire-control systems and to allow useful comparisons with unguided rockets under the same launching conditions. The bureau also promised to consider a long-term program as soon as design studies were complete.[34]

The station responded with plans to develop two prototype missiles with identical airframe, propulsion, and controls, but with guidance preset by an internal autopilot in the Type I missile, and with an additional IR-homing head that would lock onto a target for terminal guidance in the Type II missile. Experience obtained from Type I would be incorporated into the design of Type II.[35] The idea of developing alternate versions would soon be followed more successfully with the Sidewinder missile. The station's first missile differed significantly from its successor, however, in that the NOTS AM design philosophy took what McLean later described as an "easy-looking and seductive approach of welding 'off-the-shelf' components into a system."[36]

The bureau's plan was that, at the conclusion of the design engineering and preliminary evaluation phases, NOTS would collaborate with Project Meteor on "one or more designs for development of an air-to-air guided missile."[37] With its hands thus loosely tied, the Guided Missile Division considered the prospect of cobbling together the propulsion unit from the Sparrow missile, the guidance section from Dove, hydraulic valves from Nike, and one of several fragmentation warheads from existing rockets.[38] In McLean's view, this plan perfectly illustrated the pitfalls of what he later termed "design by committee with the final product clearly showing the lumpy structure representing individual enthusiasms."[39]

In mid-1948, largely because of the NOTS AM work, the station began a joint target-radiation survey project with Eastman Kodak, which had been assigned development of homing and fuzing components in the follow-on phase. The survey project's goal was to discover the IR properties of various targets, especially aircraft. Ironically, this work, which began as an afterthought, would soon become the only part of the NOTS AM work to have lasting practical significance.

Bureau efforts on NOTS' behalf did not sway the TEG from its antipathy toward the station's first missile and other in-house missile-development projects. In October 1948 the group issued a unanimous opinion suggesting that promising technology in "any of the heat seekers now under development

. . . be incorporated in an existing air-to-air missile such as Sparrow."[40] The beam-riding Sparrow I existed only in the sense that Sperry Gyroscope Company, to which BuAer had given responsibility for the entire system development, had concluded analytical studies and was working on the missile's design.[41] Arguments offered by BuOrd succeeded only in hardening the TEG's original position. In early 1949 NOTS leaders learned that a letter under preparation in the bureau would shortly discontinue the NOTS AM.[42] Vazsonyi made a quick trip to Washington and on 24 February confirmed the bad news in a high-priority telex to China Lake:

> GUIDED MISSILES PROGRAM CANCELLED. STOP ALL OF YOUR WORK ON NOTS AIR TO AIR MISSILE.[43]

The station's first missile project was thus halted almost before it began. But the mavericks on the desert had not given up on the prospect of missile development work. In August 1949 Switzer told the NOTS Advisory Board that "most of the work performed by NOTS in the field of guided missiles is confined to testing but that we have done considerable work on an air-to-air missile and are now in the process of submitting a proposal on a new idea."[44]

With characteristic optimism, McLean and his helpers had charged ahead with that new idea, applying lessons learned from the first project's failure. Sidewinder pioneer Dr. Howard A. "Howie" Wilcox later described the outcome of the NOTS AM work as having been "dismal," but added that "It was only then that our people began to think carefully and sensibly about how to do a good, integrated guided missile design."[45]

Although as yet unnamed and unfunded by the station's parent organization, the Sidewinder missile program was under way.

Incubation of an Idea

McLean's first job at China Lake as head of the Ordnance Department's Fire Control Section, offered frequent illustrations of the need for improved weapon guidance, since he was also working on the problems of the airborne fire-control systems then under development. With the advent of operational jet aircraft, these systems were of necessity becoming increasingly complex. Airborne fire-control systems, the ancestors of today's complex, computer-controlled avionics suites, were an important aspect of the station's work during the decade 1945–1955.

The station was responsible for evaluation tests of most of BuOrd's early fire-control systems. In 1947, for example, the bureau asked the station to evaluate the Aircraft Fire-Control Systems (AFCS) Mk 5 and Mk 6. Although

AFCS Mk 6, an air-to-air gun-firing system and air-to-ground rocket-firing system, incorporated provisions to accommodate for gravity, dive angle, and angle of attack, it still required the pilot to preset his rocket-firing range.

During the evaluation of Mk 6, NOTS fire-control specialists and their colleagues at the Naval Ordnance Plant, Indianapolis, eliminated the need for manual ranging by supplying the system with an APG-5 radar so that a pilot could concentrate on tracking. Flight tests proved this combination to be a great improvement over previous air-to-air gunnery systems. Mk 6 later saw considerable use in the Korean conflict. The system would soon be superseded by simpler ways to improve delivery accuracy, but for its day Mk 6 offered welcome accuracy improvements for both rockets and guns.[46]

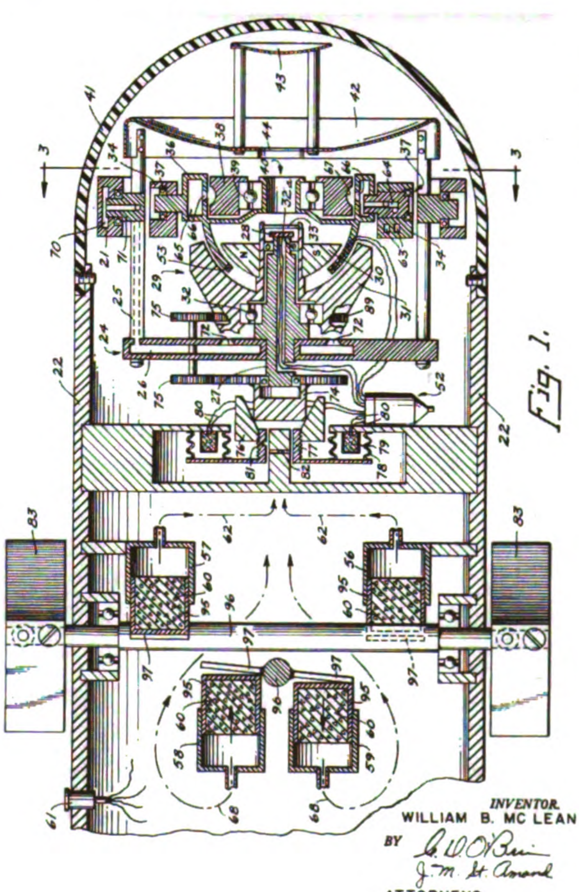
Station tests of fire-control systems led naturally to questions of how small improvements in individual components could be measured in light of all the factors affecting fire-control accuracy. Before 1948 evaluations of fire-control systems were limited to analyses of impact data laboriously collected during a large number of firings. In a major contribution to the Navy's fire-control systems, the station was the first to develop quantitative methods of assessment that allowed the variables influencing performance of a fire-control system to be measured independently of the aircraft. McLean was working in this area, and as he labored to obtain accurate data, he became increasingly convinced that fire-control systems were rapidly approaching an intricacy that would make them unworkable. A better alternative, he thought, would be to use some property of the target itself as a means of guiding an air-to-air rocket. The fire-control system could then be part of the rocket. The guidance system would need to be simpler and lower in cost than any alternative thus far devised, since the system would of necessity be destroyed with one use.

McLean did not as yet discuss his idea with the other members of the Fire Control Section or the larger Aviation Ordnance Division when he became its leader in July 1947. Instead, he thought deeply about alternatives, performing, in his own words, "much the same functions as an architect in the construction of a building." He later called this incubation period a significant component of the Sidewinder success.[47]

In the meantime, he was still responsible for developing the very systems he sought to replace. As his group studied errors in air-to-air and air-to-ground rocket fire control, measurements gathered from aircraft firings over NOTS' instrumented ranges allowed assessment of rocket impact in relation to the flight path of the aircraft firing the rocket. The group soon verified that rocket dispersion, aircraft skid, and errors in angle of attack were all likely to produce errors in fire-control predictions, but that the worst aspect of the problem was the unpredictability of the target. "Fire-control systems are very fine and quite accurate against the nonmaneuvering target," McLean said. "As soon as you put in even a half-*g* target maneuver, however, the fire control's effectiveness deteriorates very rapidly."[48]

McLean and his helpers also learned that air-to-ground targets, even stationary or slow-moving ones, presented problems of their own. For one thing, accuracy could literally be blown away by the desert's unpredictable gusts of wind. Realizing that precise knowledge of the angle of the attacking aircraft diving toward the target was vital to air-to-ground fire-control accuracy, McLean discovered to his surprise that angle-of-attack information from wind-tunnel tests performed elsewhere was so imprecise as to be virtually useless. To rectify this knowledge gap, the Aviation Ordnance Division began collecting and analyzing data from flight tests.[49]

By late 1947 McLean decided he was ready to try his guidance idea out on a few people. One chilly evening in a Boston hotel he discussed the concept with Firth Pierce, a fellow Caltech alumnus with wide-ranging intellectual curiosity and a NOTS Pasadena Annex employee since 1945.[50] Encouraged by an enthusiastic response from Pierce, McLean wrote down the conversation the next day, 19 November, in his laboratory notebook, along with a rough sketch and a brief description of what he called a "target-seeking gyro"—a device



China Lake archives

Drawing for patent application, "heat homing rocket" seeker.

that in modified form would become the "brains" of the Sidewinder missile. "As a result of the discussion I decided that the following design would make a very compact and lightweight control element," he wrote, adding that

> The alnico [aluminum, nickel, and copper alloy] rotor can be spun by air pressure and will act as a gyro. The mirror mounted on its top surface will project an image of the target which will describe a circle about [where] the heat sensitive element of the target is centered. If the target is off center the circle will strike the heat sensitive element and generate an A.C. voltage which can be amplified and used to precess the rotor by interaction between the coil surrounding the rotor and the alnico field. If the position of the mirror is adjusted properly with respect to the alnico rotor the resulting precession will be in such a direction as to turn the gyro axis toward the target. Takeoffs on the position of the gyro can be used to control the orientation of the missile.[51]

McLean later described the thought process that led to this disclosure. At first he considered using a simple homing system that would pick up only signals the missile would encounter by chance as it spun toward the target. He realized, though, that the angular rates were "such that a missile that flies on a pursuit course will always go behind the target by too much to be of much use to you." He found the implications obvious:

> Well, that meant we had to put in a gyro. And experience on the Bat missile taught us that the gyro ought to be free and not geared to the airframe, so that when you turn the airframe the gyro can sit still in space. By working on that problem, we came up with the technique of putting a coil around the spinning magnet and precessing the gyro relative to the target signal without having to resolve into the missile coordinates. The gyro could then track the target independently, regardless of what the missile was doing.[52]

At the heart of his idea was the concept of precession, or the motion of a spinning body when acted on by an external torque. A gyro moving freely within a missile body could precess in response to the infrared energy emitted by the target regardless of movements of both the target and the missile itself. A tracking telescope operated by the gyro would send signals to a control system, constantly correcting the missile's course toward its target. Thus, as McLean pointed out, the missile could solve its own fire-control problems.

Soon after that first disclosure, McLean was ready to get a small team working on a demonstration model of his invention. He called together a group of some 20 to 30 people and, with the aid of a blackboard, explained his concept.[53] A handful of the most interested, responsive attendees became his initial team.

This way of finding people to work on his project was typical of McLean's leadership style. First he would try his ideas out on anyone who listened with some degree of understanding, but he would subsequently work only with those who took independent action on the ideas.[54]

After a December 1947 test of McLean's first seeker model failed because of inadequate magnetic shielding, his small team constructed and successfully demonstrated a second model in January 1948. For this version, the group used a visible light source as a target and a photocell as a sensing device. McLean reasoned that an actual missile would use an IR-sensitive detector to track the infrared radiation from the exhaust of the jet- or rocket-powered target, but that a photocell could be used to prove the concept.[55]

Until then the seeker experiment had not needed outside funding. As Warner recalled, the modest financial needs of McLean's early work could be easily encompassed "on the truck," that is, "if he could finance it through the other projects, why okay."[56] Thompson was willing to provide in-house discretionary funds, but these limited funds would not be sufficient to support program growth into a full-fledged missile. Consequently, Thompson began efforts in early 1948 to obtain financial support from BuOrd. In February he called home from Washington to report that bureau authorities had "agreed that this station could immediately embark on a program of bread boarding a seeking system using lead sulfide cells for sensitive elements and Bill McLean's correcting gyro which would adjust the system so as to always stay pointed at the target." Funding news was not as good. BuOrd had agreed to provide no more than $100,000, Thompson reported, with these funds also intended to cover work on the IR target survey, then still part of the NOTS AM project.[57]

Despite the lack of funds, by 1948 the Aviation Ordnance Division had achieved good measurements of the major errors contributing to the inaccuracy of unguided rockets launched from aircraft, and McLean and his small team had quietly verified the central concepts of his seeker idea. He decided to learn what he could from the adolescent guided-missile programs investigating similar concepts in other organizations. Accordingly, he and several division members visited teams working on the Sparrow missile at Sperry Gyroscope Company; Falcon at Hughes Aircraft Company; Dove at Eastman Kodak Company; Terrier at Applied Physics Laboratory, Johns Hopkins University; Lark at Raytheon Manufacturing Company; Hermes at General Electric Company; and Bat and Pelican at NBS. McLean also talked to Dr. Wernher von Braun, the rocket genius of Peenemünde, the Nazis' rocket research and development center of World War II. Von Braun and his team at White Sands Proving Grounds, New Mexico, were engaged in testing and modifying the V-2 rocket, sponsored by the Army in work leading to the Jupiter program.

Of these missiles in development, only Sparrow and Falcon were designed for air-to-air use, but all incorporated technology applicable to McLean's project. He later articulated the purpose of the visits as having been "to figure out . . . the minimum amount of garbage you had to hang on the rocket in order to make it home."[58] The information he collected on the design problems of each missile program further convinced him that a useful homing rocket would not use an aircraft fire-control system. As he saw it, incorporating fire control would "essentially double your troubles; besides the unreliability problems of the fire control, you also have those of the missile." He found that each missile design shop was having a problem conquering undamped oscillations that resulted from the coupling between the missile body and the tracking loop. These oscillations forced designers to add circuitry, thus increasing missile complexity. McLean's idea would circumvent this problem, since his tracking system was unattached to its surrounding missile body.[59]

The visit to Hughes Aircraft also yielded an important design payoff. McLean's first seeker design, as presented in his patent application, incorporated two gyros, one to carry out the seeker function and the other to produce signals that would let the missile know the airframe's exact motion and orientation during each instant of its flight. The gyros were designed so that their rates of turn would be proportional to each other. Hughes engineers suggested that a proportional-navigation missile would not in principle need the motion- and orientation-sensing gyro, since the missile would correct itself as it neared the target. McLean accepted this idea with alacrity, realizing that his entire device could thus be smaller and operate with fewer components than he had previously thought possible.[60]

Cognizance and Champions

In late 1948, when Thompson encountered TEG opposition to the station's first missile program, he worried that the heat-homing rocket project might also be in jeopardy. Furthermore, he feared that if the parent RDB were to adopt the TEG philosophy, the station's very reason for existence could be threatened. He turned for help to an influential friend, Deak Parsons, by then director of the Atomic Defense Section (OP-36) in the Office of the Chief of Naval Operations.

"Dear Deak," Thompson wrote, "On my return from the east I stopped to see Fred Hovde at Purdue to discuss with him, in part, the focus of the NOTS development program for certain components for a short range air-to-air missile." Both Thompson and Parsons had worked closely with Dr.

Frederick L. Hovde, the wartime chief of Division 3 of the National Defense Research Committee. Now Thompson hoped Parsons would intercede with Hovde, who was the GMC chairman. Pointing to the TEG's negative report on the NOTS AM as evidence that "the RDB doesn't understand what we are trying to do," Thompson emphasized the need to educate the members on "the extent to which the major investments in facilities at this station have been focused on research and development activities as distinguished from test and assessment work."[61]

Parsons' direct response is not recorded. Thompson subsequently expressed the belief, however, that the station's guided-missile cognizance problems were the motivation for a remarkable memorandum Parsons wrote in February to Dr. Karl T. Compton, who had succeeded Vannevar Bush as RDB chairman in October 1948.[62] Although Parsons was careful to label the memorandum as expressing "personal views," he assured Compton that those views were based on official experience. "No one argues about cognizance of marlinspikes or saddles. But in important, partially exploited fields, cognizance can be synonymous with 'paralysis' or 'stranglehold,'" Parsons said, adding:

> In addition to the non-subtle cognizance difficulties arising from jealousy and lack of imagination there is a subtle difficulty which I believe you have to guard against. . . . This is the lack of real determination and resourcefulness of an organization in trying to defeat its own favorite development. . . . One expression of this inner conflict is in the form of a campaign to get *controlling cognizance* of any *threat* to one's favorite weapon or system. The conscious, expressed motives are always highsounding and convincing to the naive. But the ultimate practical result can be stultification and technical defeat.[63]

A pleased Thompson described Parsons' memo as "one of the best things he ever wrote."[64] With the way thus paved, Thompson sent a letter to Compton in March 1949. "I should like to mention that we are experiencing some difficulty at Inyokern, involving morale at least, because of a persistent criticism which is emanating from one panel of the RDB, regarding NOTS' efforts to do development work and some research bearing on the guided missile field," Thompson wrote. "I should not mind so much, if the criticism were about guided missiles alone, but it seems to attack the primary mission of the station. The criticism originates in the concept that Inyokern is a 'Test Station,' and therefore should not be engaged in the other activities."

Thompson then pointed to the lesson he hoped the RDB would derive from the station's experience:

> We feel that a type of operation of the above kind should be exploited much more extensively in this country in the effort to conserve professional man

> power and to avoid unnecessary duplication of work on components. . . . We are particularly anxious that there be an improved recognition among those who are designing the pattern of operation for the weapons program in this country, of the fact that there is at NOL and NOTS a very serious effort to solve those problems which must be solved, if the research and development programs of laboratories operated under the framework of service administration are to be accomplished at high levels of effectiveness.[65]

Compton's answer promised no specific support, but left the door open for further dialog. He agreed that the scientific and engineering community needed to know more about the accomplishments of the in-house laboratories. "A number of us in RDB have talked over this matter and will try to find opportunities to be helpful," he said.[66] Thompson was encouraged by this answer, which he perceived as "quite sympathetic to our point of view."[67] He realized, however, that without official support for McLean's project, the station had only the most tentative of toes in the proverbial door.

Although McLean advocated keeping his team small at the design phase, he agreed with Thompson that BuOrd recognition and additional funding would be essential to carry the project into development. On 20 June 1949, McLean published his first formal proposal for "A Heat Homing Rocket," a document designed to court the bureau's blessing. This report stressed simplicity, reliability, small size, ease of use, and low cost as program goals and cautioned that "considerable experimental and theoretical work is needed to investigate some of the proposals which are now only in the idea stage."

The proposal described a fire-control system for launching the missile on a course computed by a seeker at the end of boost, a hot-gas control servo, a proximity fuze, a canard airframe (that is, one in which the deflectable control surfaces were positioned near the nose), and an existing motor from the station's 5.0-Inch HPAG Rocket.

McLean's proposed design also included a pursuit navigation system, in which a rocket closing on a target continually decreased the angle between the boresight axis of the rocket and that of the target. Constant error correction by the rocket's navigational system would ensure that no matter which way the target moved, the rocket would immediately correct for that maneuver.[68] The design still incorporated two gyros, but McLean noted that he planned to eliminate the second gyro. A key objective of the proposal, he said, was to develop a weapon so integrated that "it is difficult to pick a starting point which does not involve the properties of all other parts."

McLean hoped that Re9, the bureau's Guided Missiles Branch, would forward his proposal to the RDB for review. Instead, Re9 denied the proposal on the grounds that the proposed device contained too many untested concepts to be feasible as a development project. Re9 recommended more testing to demonstrate the validity of those concepts. This response was not about to slow down the NOTS mavericks.

Re9 officials "feel it is a matter of policy that we should not call this another guided missile," Warner told the Research Board. "If we develop it as a series of components, we are within our realm. And then if these components happen to go together and screw into the head of a rocket, we will be all right."[69]

Infrared Radiation Studies

When McLean selected infrared radiation as the most promising type of signal to track, he made a lonely choice.[70] Most missile developers of the day opted for radar guidance, which they claimed had the advantage of being "all-weather"—a term opponents of Sidewinder would later use with discouraging frequency in their arguments against funding the program. McLean realized, however, that the advantages an IR detector would have in most combat conditions would far outweigh the limited advantage radar provided in cloudy skies. A passive IR system would provide a more focused point of energy than did target reflection from radar and would emit no energy that might warn the enemy of danger. Because military targets typically emit great amounts of IR energy, the equipment to detect this energy would be smaller, lighter, and less expensive than that necessary to detect radar emissions.

Counterbalancing these advantages was the problem that no IR homing device had yet worked reliably. The United States, Britain, and Germany had pursued research on military applications for IR since World War I. The Nazis had successfully tried out prototypes of several ingenious IR detection systems against the Allies in World War II. British efforts were also promising. Intensive research sponsored by the U.S. Office of Scientific Research and Development, yielded several clever communication and detection systems that led to postwar applications, but none successfully applied this technology to the guided missile. Little was known about the heat-emitting characteristics of aircraft. Nor did anyone have a clear idea of how the IR signatures (emitted radiation) of aircraft might be distinguished from sunlight, clear sky, clouds, and earth.[71]

Fortunately, the IR target studies that had begun with the NOTS AM were still under way, ostensibly because information gained thereby could be applied to the Dove guided bomb, which the station had been testing for Eastman Kodak Company since 1947 under a BuOrd contract. Dove's nose contained a large lead sulfide detector intended to measure an IR source and guide the missile toward this source. To be militarily useful, the missile would need to be able to discriminate among the IR signatures of targets and the objects surrounding them.[72]

Lawrence W. "Larry" Nichols.

At the heart of the target study was an infrared detector system designed by Lawrence W. "Larry" Nichols, who had built precision optical components for two Pasadena firms after his graduation from the University of Arizona. He applied this industrial experience fruitfully at NOTS, where he designed and constructed optical instruments from March 1946 on.[73]

He, Theodore R. "Ted" Whitney, and others in the Optics Section used radiometers and monochromators to measure aircraft emanations in the air and on the ground. After measurements of many different kinds of aircraft, "it became apparent that the shape and magnitude of the radiation patterns could be correlated with engine types, operating temperatures, and the position of the engine within the fuselage," Nichols reported. "When these three things were known, it was possible for us to predict accurately what kind of target a particular aircraft would make."

Finding a target aircraft against a clear blue sky was relatively easy; the problem came when sunlit objects generated interference signals. Nichols and his helpers decided to experiment with optical filters to remove as much of the sun's radiation as possible while still transmitting the target's radiation.[74] At Roger Estey's suggestion, Nichols devised a pioneering infrared detection system that involved a circular baffle, or reticle, with a slit in it. The reticle rotated in front of a lead sulfide cell that received whatever radiation came through the slit and passed it along to an amplifier in the form of electrical signals. Nichols' rotating slit increased the detector's resolution capabilities by chopping the incoming radiation into discrete patterns with measurable differences.

To demonstrate the validity of this approach, in 1949 Nichols loaded the scanner on an old TBF torpedo bomber converted to a flying laboratory and took to the skies over Edwards Air Force Base, where a tolerant, if bemused, Air Force allowed the TBF to lumber alongside jet aircraft under test. Nichols found that his scanner could detect the presence of an airborne target but not its exact location. He and others in the Optics Section began experimenting with various types of infrared detectors, optical materials, scanning methods, and reticle designs, accumulating much information applicable to the design of an operational missile seeker. Leading this effort was Estey, who had set up the optics group at China Lake in 1946 and whose focus on real-world problems was much appreciated by the station's weapon developers.[75] His pragmatic attitude rubbed off on other Research Department employees contributing to this work, notably Nichols and Ephraim "Raim" Regelson, "a gung-ho go-getter of the first water."[76] Building on the idea of Nichols' scanner, Estey suggested that it be refined to incorporate a Cassegrainian telescope mirror assembly, a device that could bring the target's reflected image sharply into focus on a rotating reticle.[77]

Hobby Shops and Hard Work

Funding constraints and lack of official recognition only motivated those developing the heat homing rocket to work harder. Enthusiasm was high. McLean was so engrossed in the project that on at least one occasion he arrived home, ate a preoccupied dinner, repaired to the garage for some tinkering, then returned to the house to ask, "When are we going to eat?"[78]

McLean encouraged small groups—later referred to as hobby shops—that had few defined boundaries and unstated, frequently overlapping task assignments. China Lake legend holds that McLean built Sidewinder in his garage, but those who worked with him in these early days remember his almost constant presence in the well-equipped laboratories and machine shop of Michelson Lab, within half a mile of his home. McLean, who did love to tinker in his garage, tested some of his early ideas through improvised experiments on his home workbench, but the ideas appear not to have incubated for long before reappearing in the workplace. As a knowledgeable member of his team observed, "McLean did not build the Sidewinder in his garage, unless you say that his garage was the Michelson Laboratory."[79]

By 1950 McLean's administrative workload had increased significantly. Warner's departure to become director of Technical Operations at the Joint Long-Range Proving Ground, Cocoa, Florida, seemed a propitious time to split his empire. In March 1950 the former Aviation Ordnance and Test (AO&T) Department became two departments, with the Measurements Division becoming the Test Department under Renzetti and with McLean becoming head of the new Aviation Ordnance Department (AOD).[80] He continued

Dr. William B. McLean seeking fabrication advice from machinist Woodrow Mecham.

day-to-day supervision of his pet project, as well as leadership of his division (retitled the Development Division). This situation, a member of his team commented wryly, "provided for rapid vertical communication."[81]

McLean consistently expressed distaste for the administrative aspects of management jobs, but accepted leadership roles "to leave avenues of freedom open" for the technical work. He compensated for his lack of interest in the administrative area by selecting a second in command whose strengths complemented his own. In AOD that person was Dr. Newton E. "Newt" Ward.[82] After earning his Ph.D. in physics from the University of Oklahoma in 1941, Ward had worked in essentially administrative jobs at the Magnolia Petroleum Company in Dallas and at the famed MIT Radiation Laboratory. Bill and LaV McLean were the first people to greet Newt and Maryon Ward when they arrived at China Lake on a blustery November evening in 1945.

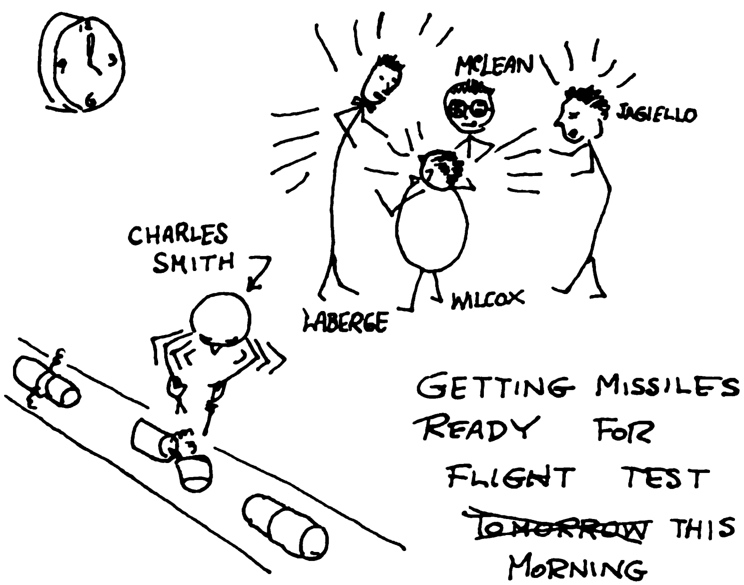
Ward began working at the Sight Laboratory, a noisy building at Armitage Field that had as its sole advantage proximity to the aircraft for which the Aircraft Fire Control Branch was developing systems.

Dr. Newton E. "Newt" Ward.

Describing administrative procedures of the branch as "like a quaking batch of jello," Ward soon discovered that he could contribute a rare skill. "It turned out I didn't have much problem making decisions, and lots of people had problems of making a decision," he recalled. "Whether we should put it here or there, it didn't make any difference to me. Put it somewhere! Get on with the business."[83]

During Ward's first years on the job, Aviation Ordnance and Test encompassed two types of work: tests of systems developed elsewhere and a growing use of station expertise to take projects all the way from initial idea through fleet introduction. McLean had chafed under a system where tests of his projects had to take backseat to tests of Lark and Terrier. In August 1947 he had made his first move to gain more control over range resources. He had convinced Warner to move Paul S. Flahive, who had been in charge of the Aircraft Projects Group, into the department staff, then had installed Ward as head of the Aircraft Projects Group. Maryon Ward recalled that at the going-away party for Flahive she had concluded that McLean had sold her husband down the river. "Newt will never be able to get these people to work with him," she remembered thinking. "They're so devoted to Paul Flahive." The host, popular range pioneer Duane Mack, had then commented, "Well, it's the end of an era and the beginning of a new era."

With Mack's accepting attitude smoothing the way, Ward soon won his way into employees' hearts. Describing himself as a leader rather than a manager, he would spend workdays visiting employees or listening to them in his office. He somehow managed to remember not only everybody's names but also the names of their children and even details like where the children went to school. This personal attention inspired fanatical devotion among employees, who viewed Ward as a firm, but fair, boss. To keep up with the minutia of his



Howie Wilcox cartoon showing work styles of the early Sidewinder leaders.

job, he would routinely plough through a thick satchel of paperwork in his living room each evening.[84]

At McLean's insistence, B-1 Range and B-4 Track became part of AOD. "This caused some irritation by the people who had the Test Department because they thought they ought to be in charge of all testing," Ward recalled. He began wrestling with several types of overhead charges, one for the Test Department, where AOD still performed many of its tests; one for the AOD employees dedicated to the test; and one for the aircraft, which needed to be paid for whether or not they flew on a particular day.

Ward soon discovered the utility of explaining department projects to the AOD clerical staff. He developed a skilled, loyal group of assistants to handle personnel matters and budgets. "I think that was one of the things that I did best of anything I did, was to bring in this lower level of people that usually are ignored, but you depend on them all the time and assume they'll be there, and I think I got good help out of that," he said.[85] Indicative of his leadership style was the action he took when the Supply and Fiscal Department asked for a list of the people authorized to withdraw materials from shop stores. He sent back a list of every AOD employee. "What a dumb question to send out," he commented later. "If we have dishonest people, let's find them and get rid of them. Let's not penalize everybody else in the meantime."[86]

With Ward and his capable staff taking care of administrative details, McLean drew enthusiasts to AOD from elsewhere at NOTS, as well as from industry and academe. In 1950 a promising crop of newcomers arrived, notably three men destined to take leadership roles in the project and on the station.

First on the scene was Dr. Walter B. "Walt" LaBerge, a tall, handsome young man with a sparkling sense of humor. LaBerge had been an NROTC cadet at Notre Dame University when World War II broke out. He had spent most of the war in the Pacific, where he was commanding officer of the minesweeper YMS-165, which under his leadership set a record, sweeping the most mines of any ship of that type. This assignment gave LaBerge an appreciation for the Navy that led him to China Lake after he completed his Ph.D. in physics at Notre Dame. LaBerge and his elegant wife, Patricia, moved to the desert in August 1950 and entered the China Lake social scene with enthusiasm. "It was a whole new life," LaBerge recalled, "and Bill and LaV McLean made it just a wonderful beginning of a marriage and of a career." Inspired by the McLeans' example, the LaBerges were instigators of costume parties and scavenger hunts using scant fiscal resources, but much teamwork, imagination, and laughter. LaBerge brought the same energy to the workplace.[87]

That same summer Charles P. "Chuck" Smith graduated from Pasadena College and arrived in China Lake. An Army veteran (discharged in 1946 with the rank of staff sergeant), he was older than most of the other new professional employees. Determined to make up for lost time, he plunged into the work, becoming so engrossed in the project that his schedule of day-and-night work earned him legendary status even on McLean's industrious team. On many occasions Smith worked the entire night, refreshing himself with catnaps at his desk. He took his hard-driving approach onto the highway, too, much to the trepidation of those who had to ride with him. A prevalent jest was that anybody who failed to keep the front office informed about what was going on would have to take a trip to Los Angeles with Chuck Smith driving.[88]

"Memories of Us" CD, China Lake Museum Foundation

Charles P. "Chuck" Smith.

The third future Sidewinder leader to arrive on the desert that year was the self-confident Howie Wilcox, who had graduated *magna cum laude* from the University of Minnesota in 1943, then became a teaching fellow at Harvard. During World War II he joined an elite group of student trainees in Los Alamos, where he learned priceless lessons from the Manhattan Project scientists. "As a result of that experience," he later wrote, "I became totally (though unconsciously) imbued with the knowledge and attitude that just about any reasonable technical objective can be realized in just a few months by a motivated team of knowledgeable young people guided by progress- and results-oriented managers backed up with adequate financial support from on high."[89]

At war's end, Wilcox followed Enrico Fermi and other Los Alamos mentors to the University of Chicago, where Wilcox received his Ph.D. in nuclear physics in 1948. He became a research physicist and instructor of physics at the University of California, Berkeley. As beneficiaries of his NOTS briefings would soon discover, he was a born teacher. The Communist scare of 1950 resulted in a requirement that all members of Berkeley's teaching staff take a loyalty oath, and after the university fired several of his most admired colleagues for refusing to take the oath, he resigned, partly as a gesture of protest and partly because he wanted to serve his country by returning to the sort of weapon-development work he had experienced at Los Alamos. He accepted a NOTS job "even though it was the lowest-paying position I was offered at that time."

The Wilcox family arrived in the middle of a three-day sandstorm, featuring China Lake's infamous "termination winds," so difficult for neophytes to endure that they could motivate decisions to quit and move elsewhere. Los Alamos had many similarities to NOTS, both in the approach to the work and in the lifestyle. As soon as the wind died down, the Wilcoxes adjusted to their new life on the desert. Evelyn "Evie" Wilcox, who had worked in the machine shop at Los Alamos, opted at China Lake to stay home and raise a family. However, as Wilcox pointed out, "she was very much a part of the ongoing enterprise, as were all the wives at China Lake."

Wilcox was delighted with the spirit of NOTS employees. As he explained:

> During World War II we were gung-ho to accomplish, and the government gave us the freedom to accomplish, and we did accomplish. . . . I will say that I found the spirit of China Lake to be very much a wartime spirit. It was the kind of spirit with which I was very much in step. I wanted to move, they wanted to move, and we just went off and made good progress without any loss of time or pace. Hey, it was great.[90]

Fresh Approaches, Simple Solutions

With energy and optimism radiating from its members, the team followed McLean's lead on several difficult problems. In the seeker-head area, he wasn't sure of the optimum approach, so he pursued several approaches concurrently.[91] By early 1950 two seeker models had been constructed. One seeker, subsequently labeled the B head, used conventional gimbal supports (similar to those used for a ship's compass) for the gyro and a nonrotating telescope mirror.[92] The other model, soon termed the A head, used a rotating mirror supported on a spherical bearing. McLean preferred the compact elegance of the A head, but he realized that it incorporated a more difficult precession technique than did the B head. He decided to test both ideas.[93]

That January McLean visited Avion Instrument Corporation in Paramus, New Jersey. He liked both the company president, Richard F. Wehrlin, and the looks of the organization, which concentrated fewer than 50 employees on one floor of a small loft building. McLean was especially impressed with Avion employee Donald "Don" Friedman, a self-starter who would fit well into the China Lake mold. Returning to the desert with the impression that Avion was "of an ideal size and capabilities" to build one of the seeker heads he envisioned, McLean convinced Thompson to release discretionary overhead funding for a contract to get Avion started.[94]

As Avion's new project engineer for the NOTS seeker, Friedman began by reviewing the pioneering "Heat Homing Rocket" proposal. "Basically, the whole system seems entirely feasible, particularly after it has been decided exactly what kind of navigation promises the optimum results," he concluded.[95] By the following September, Friedman was hard at work on the A head under an Avion contract, and NOTS had funded a third type of head assembly, a C head with a rotating motor and an internal bearing for the gimbal system.

McLean was convinced that "the decision between these types of gyro can be made only on the basis of production difficulties and it will therefore be to the best interest of the project to carry all three through the model stage." He had assigned each of the alternate design approaches to a separate team, the A head to Friedman at Avion, the B head to an in-house team under the direction of Estey and spearheaded by Lucien M. "Luc" Biberman, and the C head to another in-house team led by Jesse R. Watson. In addition to these McLean-directed efforts, Eastman Kodak Company was pursuing a parallel effort. McLean, Warner, and others from NOTS met with Eastman representatives in late 1949 and agreed to sponsor what then became the E head.[96] In November 1950 the Summers Gyroscope Company in Santa Monica began work on yet another seeker design, Type F. McLean's idea for the Type F seeker involved a gimbal-mounted gyro designed around a hollow core, with precession provided by a friction dome, an arrangement already used on many gyro instruments. Unfortunately, the station's contract with Summers neglected to stipulate that the gyro and precessing system must be free-floating and not attached to the motor case. Although the Summers alternative performed well enough to meet contract specifications, the design caused the motor case to yaw unacceptably. The station rejected the F head. "In general the design was clever but complicated by the necessary reduction gears in the friction dome system," Biberman later noted.[97]

Estey was the principal designer of the optical system, essentially identical in all versions. "All of the seeker designs incorporated a telescope that was gyroscopically stabilized inside the missile," said Edwin G. "Ed" Swann, Jr., an energetic engineer who arrived at NOTS in August 1950 and was assigned to the B head as a member of Biberman's team. "It was a clever adaptation of a traditional concept . . . that made the optical system easy to fabricate and inexpensive."[98] Typical of the informality of the work arrangements, the pragmatic Estey neither required nor received the deferential treatment he might have gotten as a relatively senior person in a more formal organization. As Wilcox recalled:

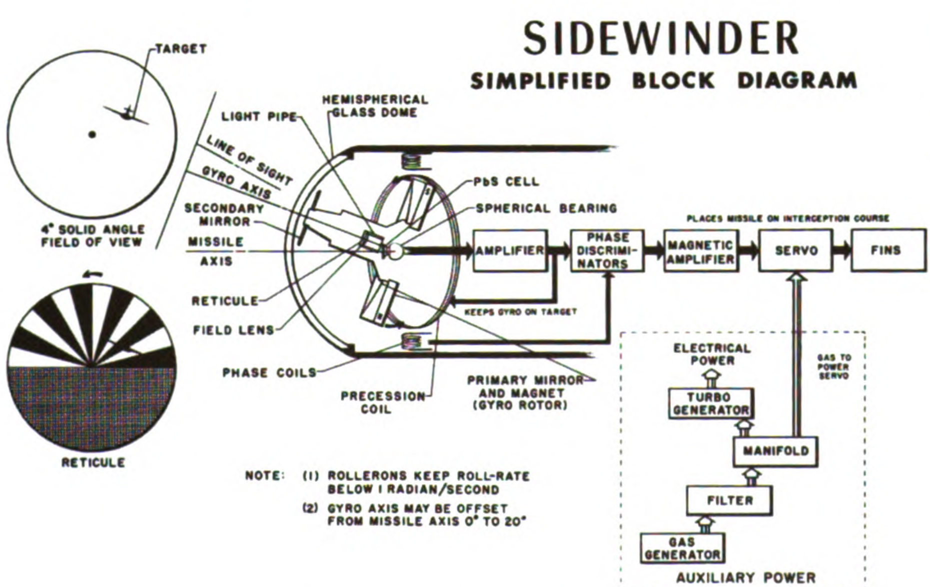
> I remember when Walt LaBerge once, as a brash young guy who hadn't been on the station more than a few months, told Roger Estey, 'Hey, Roger, we're going to have to let you go if you don't perform better,' or something like that. I just about dropped my teeth. I thought that was very funny and I think so did Roger [99]

McLean was confident that as problems arose, new ideas would surface to solve them. The team routinely ignored considerations of hierarchy and went wherever the ideas were. For example, a fresh approach was necessary to solve design problems involving airframe fin-control systems. Other missiles used complex internal coordinate systems for navigation, but McLean wanted to avoid these systems' expense and unreliability. He envisioned a navigation system that would be independent of the maneuvers of the missile itself. Central to this concept was a gyro system that tied all control signals to external coordinates.

The heat homing rocket's first gyro could move only 10 degrees, so the angle of attack had to be kept below 10 degrees. This severe limit on maneuverability made airframe control systems critically important. Complicating the problem was the fact that dynamic pressures against a missile's control fins could vary greatly at various speeds and altitudes. Other missile designers were incorporating complex schemes to predict and set missile parameters before takeoff. These settings could be calculated only by taking into consideration the expected launch altitude—a requirement that severely limited the missile's usefulness. McLean proposed to solve the problem by inventing a pneumatic servo system that would apply torque (twisting force) rather than displacement to the control fins.[100]

McLean suggested burning a solid-propellant charge to supply gas pressure to the pneumatic servo. He also perceived development of the gas generator—a small, gas-driven turbine to generate internal power in place of batteries—as crucial to the operation of his new missile. A gas generator would let him dispense with the heavy, trouble-plagued batteries and hydraulic linking devices that were causing many difficulties in other missile approaches. McLean also realized, however, that the use of gas from a servo had never before been tried on the scale he was proposing. He had begun experimenting with a pneumatic servo sometime in 1948. McLean and a handpicked group adapted a British design to the turbogenerator.[101] The China Lake Pilot Plant's rocket-development and solid-propellant experience and equipment provided an in-house source for the manufacture of experimental gas generators.

For McLean's idea to work, the torque applied to the fins by the new servo would have to be in exquisite aerodynamic balance with the fins. Fortunately, Leonard T. "Lee" Jagiello, who had come to the station in June 1946 as an



China Lake archives

Sidewinder diagram showing the missile's main components.

employee of the Ballistics Division of the Research Department, brought considerable knowledge of the laws of aerodynamics to the task.

Jagiello began work on the heat-homing rocket in a scenario typical of the way the project obtained its personnel. Wilcox had been taking data to the Ballistics Division, hoping to obtain answers on aerodynamic characteristics the airframe control surfaces would need. He remembered that the man the Ballistics Division had assigned to the project "couldn't tell me how accurate the numbers were and he couldn't stand behind them. The guy at the next desk [Jagiello] turned around and said they were accurate to five percent. . . . I instantly shifted my attention to Lee." Thus began what Wilcox characterized as "a very important informal relationship." Jagiello, according to Wilcox, was "a really extraordinarily fine aerodynamicist," someone "who could pull the truth out of data that were scattered all over the map." Even with Jagiello's help, however, Wilcox was unsatisfied with the Ballistics Division support. He offered a job in AOD, and Jagiello took it.[102]

McLean wanted the airframe for the new missile designed so that the deflectable control surfaces would be positioned forward of the fixed main wings. Jagiello's task was to design the control surfaces so that the lift forces they created would produce proportional torques at their hinge lines regardless of the missile's flight conditions. This approach meant that the team could eliminate complicated mechanisms that would otherwise be necessary to measure changing flight conditions and produce corresponding missile lift forces. "I would judge that McLean's 'torque balance control principle' avoided some 60 to 90 percent or more of the hardware complexities and dollar costs that would otherwise have been required," Wilcox said later.[103]

By borrowing from rocket technology and relying heavily on theoretical methods, Jagiello devised a half-scale model. "The first missiles built were built strictly from calculations," Jagiello said. "We had no data."[104] Undeterred by the lack of access to a wind tunnel, Jagiello and a small group of helpers created a poor man's wind tunnel. "We got a pickup from the Navy, and Mike Kamimoto hung the pole out the side," Jagiello said. "I remember at first we used an aluminum pole, and Mike got a few static electricity shocks from it. So we switched to a long bamboo pole."

The group drove the truck around Mirror Lake, a small playa at the edge of the China Lake housing area, to conduct what Jagiello referred to as "very, very subsonic tests." One of the team, Richard E. "Dick" Meeker, remembered being stopped for questioning by the China Lake police. "Now look, Moe," said Jagiello, "we're conducting an official test." Meeker recalled that this

Members of the Sidewinder team studying an early model of the missile, 22 March 1951. Sid Crockett is at center; Mike Kamimoto is at right.

information and Jagiello's authoritative attitude caused the police to back off, and the Mirror Lake tests continued without interruption.[105] Rudimentary as they were, these tests made necessary adjustments possible.

Another brilliantly simple solution came from Sydney R. "Sid" Crockett, the project's chief shop foreman. Crockett had a hard-drinking nightlife that made him less than punctual, but in the work-oriented atmosphere of NOTS, adherence to the rules counted for much less than productivity. The high-school-educated Crockett had a talent for innovation that outshone that of many of the more highly educated men with whom he worked. He had already contributed an important concept to rocket technology in his "Method of Locking and Sealing Tubular Structures," and he had been a central member of the heat-homing rocket's design team from the start. Now he applied the knowledge gained from his rocket work to come up with a solution that represented a major development in aerodynamics.

The station's rocketeers were used to dealing with the problem of rolling that occurred in flight as the thrust from the rocket's motor fought against aerodynamic drag. The most commonly accepted method to counteract corkscrewing was through a reference gyro—which McLean had already decided to avoid. Crockett suggested that little gyro wheels, subsequently called rollerons, be installed in hinged tabs, one on each of four cruciform fixed wings on the rear of the missile. As the air rushed past the missile during flight, any rolling motion would cause the affected rolleron to precess and deflect an associated tab into the airstream, thus producing aerodynamic forces in opposition to the missile's roll and dampening the roll. The rollerons were simple mechanical devices, using only the airstream as a source of power and avoiding the complex roll/rate-control systems of other missiles.

Jagiello remembered initial reactions to Crockett's rollerons as ranging from "That thing will never work" to "You guys crazy?" The fact that the concept worked, said LaBerge later, "almost required the direct intervention of the Lord to allow the gyroscopic forces to be in the correct direction so that when the missile rolled, the rollerons popped out in the right direction and cut down the roll."[106]

Jagiello's analysis supported the soundness of Crockett's proposal, and work began on two types of rollerons, one driven by gases from the rocket motor and the other driven by the airstream. The more elegantly simple solution to an aerodynamic problem proved to be the more workable, and the airstream-driven rollerons became part of the missile's design.[107]

Authorization and a Name

The more progress the China Lakers made, the more pressing was the need for additional funding that would come only with official authorization. Parsons intervened again, this time to convince Bureau Chief Noble and a group in OP-05 to remove Re9's funding roadblock by going around it.[108]

Haskell G. "Hack" Wilson, then an employee of the bureau's Fuze Research Development Section (Re2b) and later the station's technical director (1970–1973), recalled that word came down through the management chain: "Provide funds to China Lake under the title of exploratory work with fuzes." McLean's project was thus authorized to continue on NOTS foundational research funds with additional support from Re2 on the fuzing aspects of the problem. The heat-homing rocket had officially become a fuze project.[109]

On 5 October 1950, NOTS received a welcome message documenting BuOrd's first official authorization of the heat homing rocket:

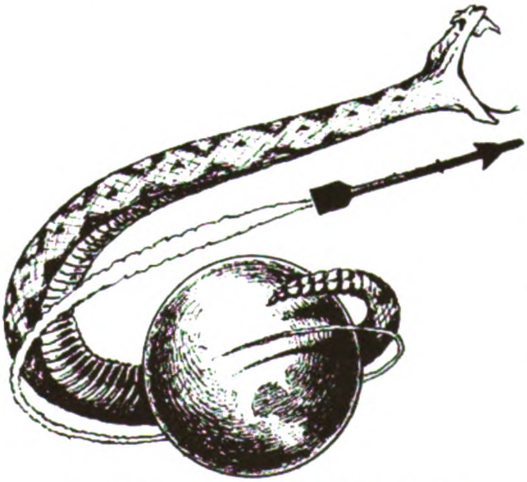
> SUBJECT SPECIAL APPLICATION OF HPAG ROCKET FOR AIR TO AIR WEAPON SYSTEM X NOTS HEREBY AUTHORIZED TO UNDERTAKE FUZE DEVELOPMENT AND COMBINED WARHEAD AND FLIGHT SYSTEMS UNDER PROJECT NOTS-RE2B-11 X ESTIMATED DATE OF RELEASE TO PRODUCTION OCTOBER 1951 AND ESTIMATED FUNDS 2ØØ,ØØØ DOLLARS X REQUEST NOTS ASSIGN CODE NAME[110]

Shortly thereafter Thompson returned from a Washington trip and spoke to the Research Board on the importance of expediting work on what the board's minutes inelegantly termed the "Tendency Fuze." Although, as McLean said, calling the missile a fuze "wasn't too bad a stretch of the imagination because the guidance unit really did screw on in the same place that a fuze screws on," it was certainly more misleading than "heat homing rocket" and scarcely more desirable than "Low I.Q. Homing Head," the name Warner elected to call the project.[111] The time was ripe for a more appropriate name.

As with many good ideas, the name selected was almost immediately recognized as the best choice. In an AOD management meeting later that October, Dr. Gilbert J. "Gil" Plain suggested that the new missile be called Sidewinder. The missile and the sidewinder rattlesnake were similar, Plain said, in that each located prey by homing on the intended victim's body heat. Others at the meeting quickly pointed to further similarities. Both snake and missile were small and deadly. Both could outmaneuver and destroy an intended victim, both had the characteristic of striking only when disturbed or aroused—and both were born on the desert. Sidewinder it was.[112]

Although McLean had a high tolerance for ambiguity in working relationships, he realized that others needed work boundaries. He formalized Sidewinder task assignments by sending a memorandum to Thompson via Dr. Frederick W. Brown, who had become the station's associate director for R&D in March 1950. McLean proposed a dozen working groups to accomplish a task the memo's subject line referred to as a "Control System and Fuze for the HPAA Rocket." (HPAA, the 5.0-Inch High-Performance Air-to-Air Rocket was a variant of the HPAG rocket, which McLean had planned from the start to use as Sidewinder's motor.) In the body of the memo "HPAA Rocket" became "Sidewinder."

McLean stated his intention "to act personally as project engineer." He already had teams for the A, B, C and E seeker heads; now he set up a D-head team to work on a very different alternative. Under LaBerge's leadership, this team


NAVORD Report 4934, NOTS 1217, For Pilots Only

Sidewinder—the snake and the missile.

was assigned to "Design and construct a test model of an optical beam rider control for the subject rocket to be used for close support work." This air-to-ground version soon acquired the name OMAR (Optically Maneuvered Aircraft Rocket).

McLean challenged a small group headed by Crockett to coordinate Sidewinder engineering design, working closely with D&P to ensure that components would be reliable and producible. W. Dale Drinkwater and an even smaller group were assigned to "Study advantages and limitations of present system, folding fin system, best aerodynamic configuration." Whitney, Nichols, and others in the Optics Section would focus on "maximum range, tactical limitations, and contrast of targets." Pauline Rolf, a mathematician in the Research Department's Analysis Branch, would do simulations, and Hugo Meneghelli and Rod McClung would work on fuzing, with Meneghelli also working on the warhead, which McLean envisioned as virtually identical to that for the HPAA rocket. McLean assigned himself the hot-gas control servo system.[113]

In mid-November Brown approved McLean's approach to the task and agreed that AOD would be responsible for the detailed administration of all tasks, with the exception of fuzing and warhead development by the Rockets and Explosives Department and target-survey work by the Research Department.[114] On 27 November McLean's team leaders met, ratified Sidewinder as the project's name, and agreed that the first day of October 1951 would be the target date for the first air-firing tests.[115] With a name, task assignments, and initial funding, the project could move on to the next phase.

McLean outlined a daunting series of tasks, but the enthusiastic Sidewinder team was ready to overcome all obstacles.

5

Years of Change

The years 1949–1950 saw many changes at China Lake. After a devastating accident in February 1949, China Lakers mourned together, absorbed the loss, and moved on.

Station leaders spent a disproportionate share of their time on attempts to gain the recruitment flexibility and community assets needed to attract a highly trained technical staff, as well as on new administrative structures to fund exploratory work and to influence the weapons planning process in Washington.

While the changes at NOTS were consistent with the philosophy upon which the station was founded, the reality of a growing Communist threat spurred changes at the national level.

A Tragic Accident

The date was Thursday, 3 February 1949. At 6:30 that snowy morning, a small twin-engine JRB transport aircraft lifted off from the Armitage Field runway of China Lake's Naval Air Facility (NAF) and headed south toward the ancient El Paso Range, then west over the Sierra Nevada. At 7 a.m. the NAF tower heard a terse "On top at 10,000 feet over Walker's Pass." Then silence.

Visibility was poor, and NAF air controllers were disturbed about the little plane's lack of radio contact, particularly when the JRB's scheduled landing time at Alameda Air Station arrived, then passed. The pilot, Commander Alphonse Minvielle, was not the sort who would fail to report in. The popular NAF executive officer had been a China Laker for a little more than a year. He had flown courageously in carrier strikes in the Pacific during World War II, survived the sinking of *Wasp* (CV-7), and returned to the states with numerous decorations, including a Distinguished Flying Cross. Lieutenant (j.g.) Charles V. Matus, the young Naval Reserve pilot joining Minvielle in the cockpit, had been on the station for only five days. A valorous veteran of World War II patrol bombing squadrons in the Pacific, Matus had also had a tour with the air-sea rescue service of the Hawaiian Sea Frontier. Now, in a departure from standard procedure, he took the copilot's seat without having been checked out in the operation of the JRB. He was assigned to the flight only because other pilots were not available. The JRB probably would not have been used that day, either, if more spacious aircraft had not been otherwise occupied. When Navajos snowbound on their northern Arizona reservations tramped out pleas for "hay" and "food" into the snow, two R4D transport planes (with 25 service personnel) from China Lake were among the 16 military aircraft that responded, airlifting more than 800 tons of hay to the sheep on the reservations between 31 January and 9 February.[1]

The purpose of the 3 February flight was to deliver a group of NOTS scientists to a meeting of the American Physical Society in Berkeley. Because of the JRB's limited seating, an initially lengthy passenger list had been pared to five: Dr. J. K. L. "Loren" MacDonald, Dr. John McKinley, Myron G. Kellogg, Rodney Morrin, and Joseph Vargus. The seven men on the little plane shared two traits: enthusiasm for their chosen fields and youth. Minvielle was 34, Matus only 27.

Kellogg, just 35 years old, had come to NOTS in 1946 after having taught mathematics in the California public school system. An employee of the AO&T Department, Morrin, 36, had joined the Research Department at NOTS in late 1945 after wartime service as a physicist in the Bureau of Ships. Vargus was also 36 and a Ph.D. candidate at Caltech. He had come to the desert in June 1945 as a mathematician in the Internal Ballistics Section. In 1948 he became a consultant in physics and mathematics on the staff of the Explosives Department. McKinley was 42 and a chemist in the High Explosives Section of the Explosives Department. After service in New Guinea interrupted his teaching career, he had returned to the University of Colorado for his doctorate in chemistry. He came to NOTS in September 1948, fresh from a postdoctoral research fellowship at his alma mater.

The oldest of the group at 43, MacDonald was a Nova Scotian with a distinguished career in teaching and research. He had left a position as a professor of mathematical physics at New York University to come to the desert just four months before and had been uncertain at first that the lure of his job as head of the Applied Mathematics Section in the Research Department would make up for the lack of social and cultural amenities. Just days before the flight, he told L.T.E. Thompson that he had made up his mind to stay.[2]

On that fateful 3 February, worried NOTS officials started a search for the missing aircraft. By nightfall more than 50 search aircraft were involved. The next day the search intensified. As the week wore on, hundreds of aircraft flew thousands of hours in one of the largest searches staged to that date on the West Coast.[3] "The first thing you heard in the morning was the planes droning out, leaving the base to search, and it was the last thing you heard at night," Maryon Ward remembered. "That was such a depressing time . . . a very sad time for all of us."[4]

A massive ground search fanned out across the desert and surrounding mountain ranges. The technical work of NOTS slowed nearly to a halt as civilian and military workers joined the search. Thompson himself joined Emory Ellis in visiting mining claims in the Panamint Range, asking in vain if anyone had heard unusual noises overhead. Other NOTS folks searched the precipitous terrain surrounding Owens Peak and fanned out into the Kern Plateau to the west. By the end of the first week, those covering the terrain on foot had spent more than a thousand hours in a fruitless search. By the second week, searchers from outside the valley had gone home. The pilots of NAF continued looking.[5]

When warmer weather arrived, Geno DeZan, a Kern County Airport official, and Clayton H. Yearick, a deputy sheriff from Bakersfield, decided to see if the melting snow might have uncovered signs of the missing aircraft.

U.S. Navy photo NP/45 021137 courtesy Gary Verver

Wreckage of JRB aircraft that crashed on 3 February 1949, killing all seven aboard.

The photograph was taken on 21 April 1949, the day the wreckage was found on the south side of a wash in Indian Wells Canyon about two miles south of Owens Peak.

On 21 April, flying north over the Sierra foothills, they spotted a flash from the sun's reflection at about the 7,500-foot level of a south-facing hillside overlooking Indian Wells Canyon. Flying closer, they discovered the burned ruins of the JRB. Later that afternoon a Navy and civilian ground party determined that the plane had crashed into the mountain and that all on board had been killed instantly.[6]

The next issue of the *Rocketeer* carried front-page photographs of the discovery. In an ironic, yet somehow comforting, juxtaposition, a small item on page 7 noted that "Little Betty Jean, weighing seven pounds, ten ounces, was born 21 April to Mrs. Helen Morrin of 110-A Byrnes and the late Mr. Rodney Morrin."[7] In the midst of tragedy, life went on.

Further healing for the community came with a simple, yet eloquent, Protestant and Catholic memorial service on 28 April at the Station Chapel. A recreation area west of Armitage Field was named Minvielle Park the following September. The pool, barbecue pits, and other recreation facilities at the park had been constructed by volunteer labor (with Minvielle himself one of the main organizers). This recreation area was used by Armitage Field personnel and their families and guests, including all residents of China Lake.

A Fresh Look at Planning and Accountability

Although the Minvielle tragedy shocked and saddened China Lakers, both the buoyancy of a youthful community and the engrossing nature of the work helped keep NOTS on an even keel. As confident as they were of the young station's technical competence, NOTS' leaders knew they still had much to learn in administrative areas. Advice flowed in from visiting groups sent to inspect management practices, but as Thompson pointed out, the recommendations weren't improvements if they slowed down technical progress.[8]

Thompson knew from experience that his strong-willed department heads would resist or even ignore mandates, but would appreciate and act on good advice. Accordingly, he and the Research Board began two important activities in 1949, both designed to receive constructive information from outside sources. One, the establishment of the NOTS Advisory Board, is discussed later in this chapter. The other brought five members of the faculty of the Harvard Graduate School of Business Administration to China Lake and Pasadena in summer 1949.[9] The Research Board asked the Harvard group to look at and recommend improvements to the entire spectrum of the station's planning and control. The idea was that once the group had given NOTS a framework, the station would be better prepared to follow on with surveys of its own.[10]

The members of the Harvard team met with employees at all levels of the organization, then prepared a thoughtful critique named the Nickerson Report for group leader Professor Clarence B. Nickerson. The report was significant both for the breadth of its recommendations and for the seriousness with which NOTS followed up on the recommended actions. Thompson later commented to the station's leaders that he believed the report "produced a very favorable feeling" in Washington, both because of the helpfulness of the suggestions and because the report showed that "the Station itself is interested in trying to reach significant solutions to these problems."[11]

Nickerson and his colleagues acknowledged that informality and lack of bureaucratic controls had been important components of the station's successes, but added that NOTS had now reached a size where "it is impossible to place complete reliance on informal procedures, and a certain amount of systematic planning and control is essential." The group cautioned, however, that new procedures should "strike an extremely careful balance between the need for informality and flexibility imposed by the nature of the work and the need for systematic method imposed by the size of the organization."[12] To keep the study somewhat more manageable, the Nickerson team avoided the larger issue of BuOrd authority over the station's programs but did not hesitate to recommend changes in NOTS operating procedures that would also affect BuOrd procedures.

The Nickerson group believed strongly that station management needed to institute more thorough procedures for accountability at China Lake and just as strongly that the bureau's attempts to manage individual projects by doling out "packets of money" led to abuses. "If a given task does not cost as much as the money allocated to it there is a tendency to think up ways of spending the money rather than returning it to the bureau," the report observed. A widespread practice of charging the wrong tasks, the group noted, "is contrary to BuOrd regulations, and in fact goes against the grain of the people who do it, but the work has to get done, and the device of making incorrect charges is sometimes the only way in which it can get done."

The group recommended a single R&D appropriation, set up each year as a result of a planning conference at which representatives from NOTS and the bureau would develop a program "consistent within itself in terms of work, manpower, and money and likewise consistent with the mission of the station." To accommodate funding for research or other exploratory work, 25 percent of the technical budget would be used at the discretion of the commander and the technical director.[13]

Research Board members studied the group's recommendations and agreed that they exhibited "a striking parallel to the principal efforts of the station to improve its procedures and operating effectiveness." Board members liked the Nickerson Report's single-appropriation and overhead-funding concepts and agreed emphatically with recommendations bearing on the need for long-range planning. "Stress *joint* BuOrd-NOTS planning; emphasize *early* planning," the department heads said, then recommended that the report's findings not be imposed whole-cloth, but that the best recommendations be implemented slowly over a year or so, with a follow-up visit to check on progress.[14]

After considering a follow-on funding proposal from NOTS and NOL, Rear Admiral Walter G. Schindler, assistant chief of the bureau for research, made a counterproposal that Thompson told the Research Board "appears to be close to the desired objective." The idea was that technical overhead funds would be assigned "through a comparatively small number of 'station projects' each of which may have several or many tasks."[15] Meeting jointly, NOTS and NOL leaders then heartily endorsed the bureau's new fiscal system, calling it "an important and necessary step" and noting the importance of "continuity of the overall fiscal support."[16]

Establishment of an Advisory Board

The Nickerson Report not only encouraged planning mechanisms linking the station with BuOrd but also reinforced actions to establish a planning group closer to home. As early as 1945, NOTS leaders had begun to consider setting up a group of expert advisors to serve as liaison with the scientific community and to help guide the direction of the station's technical effort. In 1947 Thompson had begun unobtrusively planning, organizing, and recruiting for the proposed advisory group.[17] He selected two trusted helpers—Dr. Wallace Brode, associate director of the National Bureau of Standards and former head of the NOTS Science Department (1945–1946); and Dr. Ralph A. Sawyer, dean of the Horace H. Rackham School of Graduate Studies, University of Michigan, and a wartime associate of Thompson's at Dahlgren.

Attempts to woo Brode back to NOTS as a full-time employee had proved futile, as had similar efforts to hire Sawyer.[18] Thompson, pragmatic as always, turned to other ways to enlist both men on NOTS' behalf. By bringing them to China Lake on short-term assignments, he hoped not only to capitalize on their expertise and experience but also to maintain their interest in NOTS so that they might intercede on behalf of the station as needed. Thompson had the same idea about the proposed Advisory Board, which he envisioned as an

Dr. Ralph A. Sawyer, Dr. Charles C. Lauritsen, and Dr. Wallace R. Brode, 11 November 1951.

influential sounding board for and advocate of the station's technical ideas and goals. He believed that the board would have the expertise and the objectivity to be "in a position to evaluate the progress that we make, the success that we have in doing technical work," as well as to serve as an excellent source of information for station management and for "inspection groups that really sincerely want to know whether we're doing a good job or not."[19]

After Sawyer spent a summer at NOTS laying the groundwork, Thompson was ready by October 1948 to launch the board. He wrote a memorandum to Bureau Chief Noble and enclosed a draft invitation letter along with a list of eminent men of science proposed for one- to three-year memberships. The purpose of the board, Thompson said, was not to serve as a substitute for inspection boards, but rather to "be effective in promoting the objectives which the inspections are intended to accomplish."[20] Noble, who had already discussed the idea with both Thompson and Dr. Ralph D. Bennett, NOL technical director, endorsed advisory groups for both NOTS and NOL.[21]

Switzer sent prospective board members a letter inviting them to become members of "a small Advisory Board of consulting scientists and engineers." The letter laid out a projected level of involvement that to its busy recipients must have seemed refreshingly limited: "We hope the Board can meet as a group at the station perhaps twice a year for a few days to become familiar with its facilities and acquainted with the personnel, see some of its work and discuss current problems."

Advisory Board advice would be appreciated, Switzer said, "on problems of organization and equipment, on technical aspects of individual tasks, on relations with university and industrial laboratories, on recruitment and promotion of personnel, and on similar matters of importance to the best performance of the Station mission."[22]

This letter and associated informal recruitment efforts were remarkably successful. Of the 15 names on Thompson's "wish list," 11 agreed to join the NOTS Advisory Board, despite their heavy involvement on other committees. This impressive roster—all Ph.D.s—included men who had worked together in the wartime OSRD, who knew and appreciated NOTS' accomplishments, and who could use their influence in Washington to help the station. Perhaps foremost among these illustrious members was Dr. Charles C. Lauritsen, physics professor and head of the Kellogg Radiation Laboratory at Caltech. Lauritsen's service on a NOTS advisory body seemed a fitting extension of his early and abiding interest in the station.[23]

Sawyer and Brode themselves were in the group. Robert B. Brode, a distinguished professor of physics at the University of California, Berkeley, joined his brother in the undertaking. Industrial leaders on this first board were J. A. Hutcheson, director of research laboratories at Westinghouse Electric Corporation; Mervin J. Kelly, executive vice president of Bell Telephone Laboratories; and Robert W. Cairns, assistant director of research for Hercules Powder Company. Representing academia were L.M.K. Boelter, a distinguished chemical engineer and dean of the College of Engineering at UCLA; Worth H. Rodebush, a physical chemist at the University of Illinois; and Howard W. Emmons, an engineering scientist at Harvard University.

Lauritsen was joined by two others from Caltech: Frederick C. Lindvall, chairman of the Division of Engineering, and H. P. Robertson, professor of mathematical physics. Bringing the perspective of the government laboratory to the board were Lawrence R. Hafstad, director of reactor development for the Atomic Energy Commission; and Robert H. Kent from the Ballistic Research Laboratory, Aberdeen Proving Ground.

An orientation meeting in August 1949 was designed to give the new board an opportunity to become acquainted with the station and its programs. The press of other business took Thompson to Washington that month, but an

Meeting of the NOTS Advisory Board, 27 July 1950.

From left are Dr. L.M.K. Boelter, Dr. Howard W. Emmons, Dr. Wallace R. Brode, Dr. Ralph A. Sawyer, Dr. Robert B. Brode, Dr. Robert W. Cairns, Dr. Charles C. Lauritsen, Robert H. Kent, Dr. Frederick C. Lindvall, and Dr. Worth H. Rodebush.

able substitute host for the board's first meeting was Wallace Brode, serving as a NOTS consultant in Thompson's absence. A digest of the proceedings prepared for Thompson's benefit documents that Lauritsen, the interim chairman, kept the meeting informal, yet businesslike. Discussion of a problem or a setback invariably elicited the question, "How can we help?"

The NOTS commander had an answer to that question. Commenting that the station "has more work to do than can be accomplished and that guidance is needed in selecting the proper lines of endeavor," Switzer made a significant suggestion:

> Admiral Switzer then briefly reviewed the NOL Advisory Board Meeting . . . . One result of the NOL meeting was the decision to attempt to obtain approval from BuOrd for a fixed percentage of the total budget to be allocated for basic research. The NOL Board started with 15% as a minimum figure for research. This might be a consideration for the NOTS Advisory Board.[24]

Accepting Switzer's challenge, the board began defining a procedure for what would become one of its most important accomplishments—additional funding freedom that would be a crucial factor in the station's technical creativity during the years ahead.

Discretionary Funding for New Projects

Thompson welcomed Advisory Board support for the idea of a station-administered exploratory-research fund, which he saw as important for two reasons: it would give NOTS the freedom to pursue new ideas in a relatively sheltered environment until their potential value could be proved or disproved, and it would add an important incentive for the station to use in its professional recruitment efforts.[25]

China Lake's isolation, the prestige of its leaders, and the wartime environment in which it was established had already conditioned employees to expect that entanglements in Washington would be kept to a minimum. The Caltech rocket work for the Office of Scientific Research and Development had proceeded with the relative freedom from outside constraints that is a frequent by-product of wartime priorities. The Caltech connection had also resulted in funding flexibility for NOTS in the immediate postwar period. As a section head in BuOrd's Research Division, Levering Smith had been in a good position to help the station gain an unexpected windfall. As he recalled, when the scientists returned to their normal research, Caltech still had "quite a large amount, I think it was 10 million dollars, on the books that had been advanced to them and that they wanted to get rid of."

At the request of Sage and Lauritsen, Smith arranged to transfer the money to Inyokern. "That became the nonaccountable money that much of the station, particularly the rocket facilities, operated on as locally controlled funds," he said later.[26]

This informal arrangement was an important factor in the station's success in pursuing research projects in the belt-tightening postwar years. But even though the Caltech residue was a significant sum, it soon dwindled. During fiscal 1948 the station established (with BuOrd concurrence) a 20-percent "tax" on all project funds issued to NOTS. This assessment financed the salaries of supervisors in technical departments, as well as materials and services that should appropriately be charged to project funds but that could not be allocated to specific task assignments.

At first the "tax" was not used to finance basic and exploratory research, but in December 1948 Thompson stipulated a 10-percent increase in the assessment, with the additional funds to be "used for support of certain programs which, in the opinion of the technical director and approved by the commander, are essential to a well-balanced technical program."[27] These funds were helpful, but Thompson and other station leaders agreed that a regular, bureau-endorsed arrangement for locally administered research funds was preferable.

When the NOTS Advisory Board convened for its first official meeting on 10–14 October, members discussed at length the BuOrd accountability requirements for NOTS funds and concluded:

> A proper financial support for N.O.T.S., while it must include certain specific tasks should, to as large an extent as possible, be built on tasks involving the production of complete weapons or weapon systems and should permit a maximum flexibility in changing the emphasis of the work as it progresses. Any realistic concept of such a station must also recognize that an appropriate fraction of the effort be devoted to exploratory and non-scheduled studies relating to the basic mission.[28]

Members took home copies of the Nickerson Report, which NOTS had received only days earlier. The Harvard group's proposal to establish a 25-percent discretionary overhead fund was as popular with Advisory Board members as it had been with NOTS department heads. "This is certainly the way to finance special projects and to take care of differences between cost estimates and actual spendings on a task," Sawyer wrote Thompson, agreeing that NOTS needed more budgetary flexibility and less detailed bureau control. "This matter, of course, was discussed by the Advisory Board and I expect that the Advisory Board will keep hammering at it," Sawyer said.[29]

An opportunity for further "hammering" soon arrived. A joint meeting of the NOTS and NOL Advisory Boards with BuOrd leaders in Washington on 31 January and 1 February 1950, resulted in a statement recommending that the bureau follow a policy already adopted by Re to provide discretionary funding for the two laboratories.[30] As a result of this joint proposal, the bureau agreed to set up a "Foundational Research fund" to be used at the discretion of each technical director to allow an uninterrupted program of relevant research.[31] A June allotment of technical overhead funds carried with it the stipulation that not less than half of the allotment should be used to fund foundational research, which BuOrd defined as "that type of research which applies to weapon trends and to the broad field of naval ordnance."[32]

With bureau support thus assured, the station began setting aside 10 percent of the money assigned to its R&D projects for research contributing to these projects. This practice proved so successful that a 1952 Naval Inspector General audit found that the fund "stimulated independent development of ideas and effectively exploited a high-class technical staff" and urged BuAer to consider adopting a similar fund.[33] Over the years station leaders viewed the fund as critically important to the work at China Lake. Sidewinder, Walleye, and other important new products might never have reached fruition without their early support from station discretionary funds.[34]

A New Commander for NOTS

By the time the Advisory Board had its first formal meeting, Switzer had left China Lake to become Commander Task Force 81 (Operational) and Commander Carrier Division 17 (Administration). On a brilliant Friday morning, 23 September 1949, Switzer had turned over the helm to Captain Walter V. R. Vieweg, who arrived highly recommended by Captain Sherman E. Burroughs, the station's first commanding officer.

Vieweg's training and fleet assignments boded well for his success at China Lake. A native of Buffalo, New York, he was a graduate of both the Naval Academy and the aviation ordnance course of the Academy's postgraduate school. He became a naval aviator in 1932. During World War II he served on *Chandeleur* (AV-10) in the South Pacific; as Staff Commander, Carrier Division Five, Fast Carrier Task Force, during the Hollandia and Marianas campaigns and early Bonin raids; and as commanding officer of the carrier *Gambier Bay* (CVE-73).

From Academy days onward, Vieweg's friends called him "Bowser" in recognition of his bulldoglike personality. He possessed unusual physical


U.S. Navy photo LHL 24020

Rear Admiral Wendell G. Switzer and Captain Walter V. R. Vieweg, October 1949.

Luau at the Officers Club.

Ann Vieweg gestures with a ti leaf to her husband, Captain Walter V. R. Vieweg and two beauties on his arms, B. J. Patton (to his left) and an unidentified partygoer.

strength and extraordinary courage, attributes that he was called on to demonstrate in an October 1944 encounter off Samar in the Battle of Leyte Gulf when enemy ships attacked *Gambier Bay*. As Vieweg's ship took blow after blow from Japanese vessels, he fought on, exposing himself to heavy fire. After he gave the order to abandon ship, he was the last man to leave *Gambier Bay* alive, still trying to find survivors. Finally, driven back from the ship's interior by hot, toxic smoke, he was forced to jump into the shark-infested waters.

Within minutes *Gambier Bay* over-turned and slipped into the deep. Vieweg estimated that she had taken nine 14- or 16-inch hits from battleships and 28 6- or 8-inch shells from cruisers, with probably half a dozen hits inflicting fatal damage. His gallantry during this encounter earned him the Navy Cross.[35]

After the war Vieweg reported to the Bureau of Aeronautics, where he was chairman of the board selecting Point Mugu, California, as the site for BuAer's Naval Air Missile Test Center.[36] He served briefly as commanding officer of *Commencement Bay* (CVE-105), then took command of the U.S. Naval Aviation Ordnance Test Station, Chincoteague, Virginia. In 1947 he became commanding officer of *Kearsarge (*CVA-33), serving in that post until he reported to NOTS.

Vieweg had solved plenty of tough management problems in his career, but NOTS, with its largely civilian work force and its spectrum of community services, presented a challenge of a new magnitude. Determined to make the most of his assignment on the desert, he soon fell in love with the place.[37] Discussions with Burroughs had given Vieweg some familiarity with the station's programs and philosophy. As a guest at an early Research Board meeting, the new commander demonstrated that he had taken the NOTS philosophy to heart. "I will not ever be so bold as to cast myself in the role of a scientist, which I am not, or dare in any way to attempt to play the role of one," Vieweg said, expressing his intent to "run this station based on the advice of those best qualified in the field." He added a reasonable request, "I ask you folks to keep me informed, and sell to me those things I will someday have to sell to the Chief or the people he works for."

"I have nothing to add, except to indicate our wholehearted support of your command of the Station," responded an impressed Sage.[38]

Recruitment Difficulties

One of the first problems Vieweg encountered at NOTS was a perennial one for the military laboratories during the postwar decade—how to attract and retain competent scientists and engineers in an environment of salary restrictions, rigid job classification standards, and cumbersome hiring and firing procedures. Industrial organizations had no such restrictions and thus usually won out in the competition for new professional employees. As Thompson complained, government contractors in need of technical talent were "continually attempting to proselyte key employees of this activity."[39]

The recruitment picture at NOTS wasn't entirely bleak, since enthusiastic China Lakers were frequently successful at convincing colleagues to sacrifice comfort and convenience for adventure and a stimulating work environment. But relatively low salaries and cumbersome hiring practices such as "assembled examinations" of candidates for scientific and engineering jobs made recruitment difficult for the station and other government labs. In early 1947 the Navy's Office of Industrial Relations (OIR) had established a West Coast office of the Joint Board of U. S. Civil Service Examiners. This office was a tenant activity of Pasadena Annex, a proximity that at first helped streamline recruitment and classification actions for the station, as well as for NAMTC and the Navy Electronics Laboratory in San Diego.

In 1949, however, the U.S. Civil Service Commission decided to issue a nationwide announcement once a year for entry-level professional positions (grades GS-4 thorough GS-7), then administer tests and set up registers (rank-ordered lists for establishing hiring priorities) based on the test results. The West Coast installations learned of this plan when the commission turned down the Pasadena examining board's request to announce unassembled examinations for entry-level professional grades, insisting instead on a nationwide assembled examination. Leaders of the affected laboratories were horrified, fearing that even if the most desirable candidates were willing to take the test, they would accept positions elsewhere rather than wait five to six months for their names to appear on the register.[40] Furthermore, the laboratory leaders pointed out, the four years of study reflected in a college transcript provided much better evidence of technical competence than did a three-hour test.

At the urging of Dr. Royal Weller, Point Mugu's first civilian chief scientist, the three affected organizations jointly worked to enlist OIR to their cause.[41] OIR gained a partial concession from an otherwise intransigent commission: the examinations could continue in regional locations, including Pasadena. But the commission ignored the argument that examinations were not an acceptable way to find technical talent. "It seems to me that the commission has completely missed the point on what it takes to get good junior scientists," noted an exasperated Vieweg.[42]

Until the urgent needs of the Korean conflict caused external regulations to ease, NOTS and other similar organizations would have to work within a cumbersome recruitment system.

A Grim Housing Situation

As the station managed, despite bureaucratic obstacles, to attract new employees, the hiring problem eased somewhat. But from the time construction of the "village" began in 1944, NOTS had been unable to house employees adequately. The problem reached crisis proportions in the early 1950s, as a flood of new scientists and engineers arrived. Housing authorities made frantic efforts to keep ahead of the demand, assigning new employees to whatever quarters were available.

A popular "funny film" created for AOD's 1953 Christmas party began as a dusty sedan careened to a stop several miles west of the station gate and dumped out a bewildered-looking young man, introduced as "J.P." in honor of the station's junior professional program. In due course the travel-weary J.P. arrived at his assigned housing, only to find a one-room tar-paper shack with no door, bare springs for a bed, a chamber pot in one corner of the room, and a tumbleweed standing in for other furnishings. "Our hero can't help but compare these fine facilities with the dorm room he recently vacated at the University of Wisconsin," intoned the narrator.[43]

China Lakers watching the film laughed knowingly. Many in the audience had experienced living arrangements scarcely more luxurious than those depicted on the screen. When Jack Crawford, for example, arrived at NOTS in 1950, he was assigned to "transient quarters" consisting of one two-story building for males and another for females. Each building had an open corridor down the center with cubicles on either side. "Four persons were housed in each cubicle with two double-deck bunks and four narrow closets (about 2 feet wide) for personal effects," Crawford recalled.[44] Other housing options were even less private. After a month or several in transient quarters, new professional employees typically moved into smaller dormitories, single-story buildings later used for offices and a childcare center. Crawford remembered his dorm room as "a real step up from transient quarters, two people to a room, lockable door, space for a dresser and closet each."[45]

As crude as single quarters were, the situation for married employees was worse. Family quarters were nearly nonexistent. Even NOTS' ordinarily sanguine recruiting literature cautioned potential employees that they should not plan on moving their families to China Lake for the first 18 to 24 months.[46] Frequently the promise of challenging work was not enough to compensate for the family disruption that went along with a new job at NOTS. The percentage of potential employees turning down employment offers was discouragingly high (50 percent in 1950). Station management blamed much of this rate on the housing situation.[47]

Exacerbating the problem were provisions of the National Housing Act, which bound the Federal Housing Administration to certify that a continuity of demand existed before it could guarantee new-housing loans. Community Manager John O. Richmond tried hard to convince the FHA that the Navy had a long-term commitment to remain in the Indian Wells Valley, yet FHA officials remained adamant that the station was a temporary installation and therefore a risky investment. As a result, the NOTS commander was forced to become landlord for most of the civilians as well as for the military personnel stationed at China Lake.[48]

Without housing loans, home ownership in Ridgecrest was virtually impossible for most young families. The few pioneering spirits who constructed their own homes were rare enough to be newsworthy. "Dr. Gilbert J. Plain, a physicist in Aviation Ordnance, feels he has nothing much to show for the $4,500 he has paid in rent during the five years he has lived at 702-A Essex," a 1951 issue of the *Rocketeer* reported. "He has plenty to show, however, for his spare-time work during those five years. It's a brand new house in Ridgecrest." Gil and Felice Plain continued to live at "Plain Acres" for nearly half a century.[49]

More typically, young professional families crowded into base rental quarters, convinced they would stay for only a few years before seeking opportunities elsewhere. So many of those families ended up staying permanently that newcomers' claims of "a couple of years, then we'll leave" were later greeted with wry smiles. In the early 1950s, however, Spartan living conditions generally meant that a long-term commitment to the community would have to incubate for a few years. In addition, many employees privately agreed that home ownership in Ridgecrest was a shaky venture.[50]

With efforts to encourage home ownership making scant progress, NOTS housing authorities worked zealously to provide rental housing. The 120 new two- and three-bedroom concrete duplexes that opened for occupancy in February 1950 were rapidly filled.[51] But the housing situation was still a problem of major proportions. Ever since the first China Lake housing opened in 1944, rental units had been apportioned to the NOTS departments for assignment. Each department had its own waiting list and assignment rules, and employees transferring between departments usually kept their assigned homes. Department staffs were forced to administer house-borrowing-and-lending procedures of Byzantine complexity. Rose Gonzales, who had arrived at NOTS as a member of the WAVES in 1944, was responsible for one of the lists. She recalled that "people would look and see what their seniority was, and

U.S. Navy photo NP/45 22953

Ridgecrest housing, August 1949.

U.S. Navy photo NP/45 22558

Hawthorne housing at China Lake, July 1949.

Each of these duplexes, built in 1946, had a one-bedroom unit on one end and a two-bedroom unit on the other.

they'd check against other departments, and they'd transfer there because they had a better chance for a house." She had to scramble to keep track of the houses that departments borrowed back and forth in their efforts to retain valuable employees.[52] In June 1950 a more equitable system went into effect, and the departments gratefully turned over housing administration to the community manager. Under new rules adopted by the Administrative Board, five eligibility groups were established, with assignments on the basis of seniority and family size. A department head could petition the commander to move a desirable recruit higher on the list.[53]

Further housing relief came that September when the Bureau of Yards and Docks approved a house-trailer court southwest of the Public Works area for 150 Navy-owned trailers and 100 employee-owned mobile homes.[54] Construction of the 11-acre court, including centrally located bathroom and laundry facilities, was completed hastily, and by early December the first family moved in. For $24-a-month rent (including utilities), military and civilian families were grateful to obtain living quarters, even in a trailer less than 25 feet long, with a tiny 176 square feet of living space.[55] Efforts continued to convince BuOrd to authorize the purchase of more trailers. Cited as evidence of the need was the station's plan to hire 500 more civil-service employees before July 1951, as well as a waiting list containing the names more than 600 employees, about 400 of whom were among the 1,100 people in dormitories, huts, and transient quarters.[56]

By late 1950 the station advised the bureau, "The lack of housing is adversely affecting the technical program at NOTS in an increasing amount. . . . Recruitment of new employees is approaching a standstill particularly in professional and higher per diem grades."[57] Shortly thereafter the bureau approved an increment of 100 more spacious trailers, and the commander was able to modify the housing rules that gave some relief to married professional employees, particularly those in the critically needed draftsman and engineering-aide categories.[58] Crawford considered himself lucky to be among those assigned to share the new trailers. He luxuriated in having a private bathroom. "On the down side," he said, "the frequent windstorms were a 'moving experience' in those trailers." Lack of privacy was still a problem. "A newly married couple moved into the trailer behind mine and since our bedroom windows opened toward each other, their conversations at night could be heard clearly. Night after night the fellow would explain the principles of rocketry and obscure physics principles to his new bride."[59]

Although NOTS pioneers later cited the neighborly housing arrangements as a cause of camaraderie, living quarters that close were clearly too much of a good thing. Plans for a longer-term solution were already under way, however. In July 1949 the 81st Congress passed the Wherry Bill, amending the National Housing Act by adding a new Title VIII that authorized the FHA to insure mortgages on private rental housing constructed to serve military installations. The bill was designed to help relieve housing shortages near military installations by giving private builders special incentives. An entrepreneur authorized to carry out a Wherry housing project was required to provide only 10 percent of the project's cost. Loans for the remaining 90 percent would be guaranteed by the FHA.[60] In August 1949 the station requested 741 housing units in China Lake under the Wherry Bill, and in May 1950 the Secretary of the Navy authorized construction of 497 Wherry Act housing units in the Indian Wells Valley, subject to selection of an acceptable sponsor.[61]

A search for a suitable site for the new housing turned up three possibilities in Ridgecrest and one in eight miles to the west. After rejecting two Ridgecrest locations because "the proximity of stores, taverns and trailer courts . . . did not add to the attractiveness of the site," Vieweg expressed an early preference for the third Ridgecrest location, "Rocket Town." Much of this sparsely populated acreage five miles south of the NOTS main gate was owned by the Transcontinental Land and Water Company, which had been trying with little success to encourage land speculators to invest in the area.[62] But Rocket Town contained so many small, individually owned lots that Vieweg reluctantly

U.S. Navy photo courtesy Inyokern Airport

Welcoming ceremony for the first commercial airline flight from Inyokern Airport, 26 February 1951.

From left are stewardess Frances Drew, Captain Walter V. R. Vieweg, stewardess Julie Abram, Colonel Shepard (president of California Central Airlines), Inyokern pioneers Gladys and Clarence Ives, and Capt. Clement R. Criddle, NOTS executive officer.

concluded that the negotiations necessary to acquire a contiguous parcel of appropriate size would make acquisition virtually impossible. He decided to recommend the Inyokern location, which he presumed would be easy to acquire, since the entire parcel had one local owner, Clarence F. Ives.

After the Navy arrived on the desert in late 1943, Ives had seen his entrepreneurial plans to develop the village of Inyokern foiled by Ridgecrest pioneers Joe Fox and Wilbur Stark, whose offers of inexpensive land for churches and other public buildings had helped station leaders decide to establish the permanent base adjacent to Ridgecrest. Ives now proposed bringing Wherry housing to Inyokern by selling 295 acres south of Inyokern and west of U.S. Highway 395 to the housing sponsor for the token sum of a dollar. Vieweg liked the idea, since accepting the offer would free up more money for house construction.[63] By September the FHA approved the Inyokern site, and Ives and his wife signed an option agreement deeding the 295 acres to NOTS for a year pending selection of the Wherry housing sponsor.[64] Finding a builder interested in sponsoring the housing, however, would not be easy, since provisions of the Wherry Act also spelled out construction costs and rent controls.

As negotiations dragged on, community discontent became more vocal. When Vieweg received an anonymous letter in January 1951 complaining about "the garageless, porchless, crowded-together houses on the Station" and "house trailers parked like a shantytown instead of neat housekeeping apartment units," he had the letter published in the *Rocketeer*, along with his reply detailing steps being taken to deal with the situation. "If anyone at China Lake can suggest additional measures which have not been taken to this end, the commander will be glad to decorate the suggester for valor," he added.[65] Within the next few years, thanks in large measure to the continuing efforts of the NOTS commander, the housing situation would ease. In the meantime, China Lakers learned to make do with whatever housing they were assigned.

Changes Within the Defense Establishment

Even as the station's leaders coped with administrative problems at China Lake, larger changes within the defense establishment would ultimately affect the projects assigned to NOTS, as well as its relationship with Washington. When the Office of the Secretary of Defense (OSD) was established in 1947, it was limited in size and authority on the recommendation of James V. Forrestal himself.

But the nation's first Secretary of Defense soon realized that he had tied his own hands. As Forrestal put in 16-hour days, assisted only by an impossibly small three-member civilian staff, the workload of his office mounted. Worse, by pursuing his initial wish to avoid overcentralization and foster cooperation, Forrestal found himself without the tools he needed to function effectively as arbiter among increasingly fractious stakeholders competing for limited defense resources. The National Security Act of 1947 had stipulated that the military departments were to be "separately administered," retaining powers not vested in OSD. As a consequence, the services often went their own way, dealing directly with the President, the Director of the Budget, or Congress, and scarcely troubling to inform Forrestal of their actions.[66]

Acknowledging that major changes were needed in the way the defense establishment was administered, Forrestal asked Director of the Budget Frank Pace, Jr., and Special Counsel to the President Clark M. Clifford to work with him on a reorganization plan. In February 1949 Forrestal and his colleagues sent the President a memorandum recommending legislation converting the National Military Establishment to a Department of Defense and giving the Secretary of Defense "effective direction and control" over the armed services.

Secretary of Defense
James V. Forrestal.

The Forrestal-Pace-Clifford memo reinforced a November 1948 report by the Eberstadt Task Force, a subcommittee of the Commission on Organization of the Executive Branch (known as the Hoover Commission in honor of its chairman, former President Herbert Hoover). The task force, under the chairmanship of Forrestal's long-term associate Ferdinand Eberstadt, recommended that "civilian influence must be dominant in the formulation of national policy and that civilian control of the military establishment must be clearly established and firmly maintained." An overhaul of OSD was necessary, the task force said, to give the office more authority, particularly over the budgets of the military services.[67]

President Truman adopted many of these ideas, incorporating them in his recommendations for amending the National Security Act, which he sent Congress in early March 1949. Congress acted promptly on one of his proposals, setting up the position of Under Secretary of Defense on 2 April. But congressional action on the rest of the amendments was delayed by a series of dramatic events following Forrestal's embittered 26 March resignation.

On 1 April the burly, blunt-speaking Louis A. Johnson became the nation's second Secretary of Defense. The new secretary had many political friends in Washington, but he was unpopular among military leaders, who viewed with alarm his inexperience in defense matters. Furthermore, he was not someone who felt the political waters before taking action. During his first week in office, Johnson abolished nine interservice boards. By the end of two months, he had wiped out 68 committees. By the end of the year, he had disbanded 141 committees, in the process making enemies in all three services and in Congress.[68]

Johnson also decided to reduce defense spending by taking early action to resolve a dispute that had been festering between the Navy and the Air Force. The Navy and its supporters in Congress advocated construction of a flush-deck supercarrier large enough to accommodate aircraft armed with five-ton atom bombs. The Air Force and congressional adherents of strategic air power wanted the funding necessary to build B-36 bombers sufficient for a 70-group capability. Funding both the carrier and the bombers was not an option, since the President was adamant that he would not approve a budget requiring large-scale deficit financing.[69]

Forrestal, who had worked hard to maintain an even-handed policy on interservice matters, had authorized the Navy's supercarrier, and in August 1948 the Newport News Shipbuilding and Drydock Company had received a contract to construct the 65,000-ton *United States* (CVA-58). However, on 22 April 1949—three months before Congress began considering Truman's reorganization plan to increase the authority of the Secretary of Defense and four months before Congress passed the implementing National Security Act amendments—Johnson rescinded Forrestal's decision and canceled the supercarrier construction project.

The Navy, which had widely publicized the keel-laying ceremony of the *United States* only five days earlier, viewed the cancellation as a severe blow to its effectiveness and prestige. So upset was Secretary of the Navy John L. Sullivan that he resigned in protest. Undeterred, Johnson handpicked Sullivan's replacement, Francis P. Matthews, a corporation executive scathingly referred to among disgruntled Navy brass as "the rowboat secretary," referring to his limited experience in matters nautical.

As these events unfolded, both houses of Congress held hearings on the administration's proposed amendments to the National Security Act, particularly Title IV, the budget section. Legislators were persuaded by arguments from witnesses—including Hoover and Eberstadt—that streamlining the preparation and execution of the military budgets would result in a more cost-effective, businesslike approach. The Senate approved the amendments on 26 May. In the House, however, members were preoccupied with Johnson's decision favoring the B-36. The House committee reviewing the amendments voted to suspend hearings in favor of conducting a probe into the controversy. President Truman then forced action by threatening to invoke executive powers. On 18 July Congress received his Reorganization Plan No. 8, containing most of the provisions in the Senate legislation. Thus maneuvered into action, the House passed its version of the legislation, and on 2 August 1949, the National Security Act Amendments of 1949 became law.

The legislation officially replaced the National Military Establishment with the more centralized Department of Defense, headed by the Secretary of Defense, who was given more control over the Research and Development Board, the Munitions Board, and the military services. The term "department" was more than just semantics, since it signaled that the Secretary of Defense was the principal military advisor to the White House. His three special assistants became assistant secretaries, and he acquired a deputy secretary. He also became the sole Defense Department member of the National Security Council. Perhaps most significantly, Title IV of the act gave the secretary the authority to distribute congressionally appropriated funds, a power that had previously rested with the military services, which, with the 1949 amendments, lost their executive-branch status and had to work within budget controls established within the department. The changes wrought by the amendments have been seen as deeply significant in that they marked the beginning of a gradual transfer of power from the military services to the Secretary of Defense.[70]

For NOTS, the shift of power at the national level at first made little difference, since funding still flowed through BuOrd, whose leaders offered strong support for the philosophy under which the Navy's desert lab had been founded. But ultimately the trend toward more centralized decision-making would affect even the magnificent mavericks of NOTS, circumscribing their independence of action and requiring them to spend more time coordinating and less time accomplishing the work.

Symptoms of Communist Expansion

As the decade neared its end, a series of unwelcome world events shocked America's military leaders into the realization that maintaining an unprecedented peacetime level of preparedness would be required in a world where peace was a relative term. Wartime technology advances had made possible increasingly precise and sophisticated weaponry that would allow military forces to operate with more versatility than ever before. Increased funding would be needed to develop and maintain these new weapons. The political climate, however, was one more conducive to budget cuts.

The war between the Communist and Nationalist Chinese had been raging across the Asian subcontinent since the end of World War II, but the U.S. had paid scant attention, choosing instead to focus foreign-policy attention primarily on Europe. After crises in 1948 in Berlin and Czechoslovakia convinced American policymakers that the Communist threat was growing, Western diplomatic efforts to establish a mutual defense treaty escalated. On 24 August 1949, the North Atlantic Treaty became effective, with the signatory nations agreeing that an armed attack against any European or North American nation would be considered an attack against them all.[71] In the meantime the armies of Mao Zedong had succeeded in forcing Chiang Kai-shek's Nationalist government off the mainland and onto the offshore island of Formosa (now Taiwan). By 5 August 1949, vast mainland China was in Communist hands.

The American public, alarmed at last by the situation in China, soon learned even more upsetting news. Air Force detection equipment found atmospheric evidence that the Soviets had detonated an atom bomb in late August.[72] On 23 September—only 49 days after the Communist conquest of China—a White House announcement officially confirmed that the American nuclear monopoly had ended. U.S. scientists were astonished that the Soviets had the bomb so soon; scientists had assumed that America had at least a five-year grace period before the USSR could create a working nuclear device.

Although efforts to clarify how America would use its nuclear might as a world power were already under way, the Soviet A-bomb explosion and the strengthened Communist presence in China shocked U.S. strategic policymakers into intensified action, as did the news in January 1950 that German-born nuclear physicist Dr. Klaus Fuchs was a spy for the Soviet Union. Fuchs' wartime work at Los Alamos had given him extensive access to information about U.S. nuclear weapons including the "Super," the still-theoretical hydrogen bomb. As a consequence, many in Washington were fearful that the Soviets would be the first to possess this most powerful of weapons. The Fuchs crisis became public in early February and exacerbated a national paranoia symbolized by the strident cries of Senator Joseph R. McCarthy (R-Wisconsin) and others that the Truman administration was "soft on communism."

The President realized that something would have to be done in response to these events, yet he was reluctant to espouse a military buildup, which he feared would be strategically provocative as well as economically inflationary. Congress, in deference to the American public, was unwilling to repeat the belt-tightening days of World War II, and Truman's policy of retrenchment was carefully designed to balance the budget and reduce a huge wartime debt.[73] Indeed, during the years 1946–1950 nearly half the money expended on defense—$42 billion of a total $90 billion—went to liquidate the costs of World War II.[74] The White House and the Bureau of the Budget, ever sensitive to politics, kept a constant pressure on the services to minimize new obligations, stretch out programs, and economize in other ways. The results included strength levels of the U.S. armed forces that by June 1950 were scarcely more than the low levels reached in 1947 at the end of World War II demobilization.[75]

On 31 January 1950, Truman took two important steps: he formally directed the Atomic Energy Commission (AEC) to begin development of the

"Super," and he charged Secretary of Defense Johnson and Secretary of State Dean Acheson with a reexamination of the nation's "entire military posture" in light of the Soviets' atomic breakthrough. A joint State-Defense study group put together a five-year military-security plan, the famed policy paper, "United States Objectives and Programs for National Security," referred to as NSC 68.[76] This paper, sent to the members of the National Security Council at Truman's direction on 14 April 1950, recommended a broad political and military program to contain the Soviet system "by all means short of war."

The report made no mention of costs, but the study group's preliminary calculations indicated that annual appropriations on the order of $30 billion to $40 billion—approximately three times the amount Truman had in his military budget for fiscal 1950—would be necessary to accomplish the recommended military expansion. Even without the dollar figures, NSC 68 was unpopular with those who had staked their reputations on economy in military spending. Truman deferred final action on the report until the budgetary implications could be assessed.

Events in Korea soon made a military buildup much more politically acceptable. The recommendations of NSC 68 had longer-term significance as the basis for a national security policy that committed the United States to an expanded role in defending other countries around the world.[77] The increased emphasis on atomic weapons that NSC 68 represented would also result in new projects for NOTS, with technical expertise acquired through the development of nuclear weapons also laying the groundwork for sophisticated conventional weaponry.[78]

6

A Broad Spectrum of Work

While the nation's leaders struggled with organizational and funding issues, NOTS worked on concepts and products extending across the spectrum from basic research to development to test to production and fleet introduction. This book covers only a few prominent programs in any detail, with each considered as a separate entity. In reality, station employees pursued many programs concurrently, with solutions to one project's design problems often applied immediately to those of other projects. The goal was better ordnance for the fleet, and to meet that goal station employees went wherever the expertise was—across projects or across departments.

Research at NOTS

Station research capabilities at mid-decade were strong and broad, with work concentrated in four main areas: ballistics, chemistry, mathematics, and physics. One of the first divisions formed at China Lake was the Ballistics Division, important in those days of rocketry for its ballistics research and range-measurement studies. The division began in a Quonset hut with only four people, but soon expanded into an entire wing of Michelson Laboratory, where as many as 35 specialists in exterior ballistics, aerodynamics, aeroballistic analysis, and ballistic instrumentation worked on exploratory research and problem-solving in such areas as crosswind firing and fin-spin investigations. The ballisticians were responsible for predicting rocket accuracy, taking into account the impact of wind and other variations in flight conditions, as well as anomalies in the rocket and its components. In the pre-computer era, the labor-intensive computations required for each study were performed on Friden and Marchant calculators.

A recurrent discussion within the division, and one that surfaced frequently in the minutes of the Research Board, had to do with what the group's proper role should be. Division members held at least three views, with one group saying that research should be the primary function, a second holding that analysis supporting specific weapon projects was more important, and a small

Dr. Ivar E. Highberg at the blackboard.

third group arguing that the division should work on its own hardware projects.[1] Dr. Ivar E. Highberg, a hard-charging, crusty ballistician who headed the Ballistics Division from 1951 until he was appointed head of the Test Department in 1955, espoused the philosophy that 70 percent to 80 percent of division employees should be doing "bread-and-butter work" on practical tasks like calculating range tables, obtaining aerodynamic data through wind-tunnel tests, and doing aerodynamic calculations on how to build or strengthen fins. Somewhere around 10 or 15 percent should be identifying problems and helping solve them. "I am also, then, willing to have about 5 percent . . . hidden off in a corner doing something that the chances are 1 in 50 that it will ever amount to anything," he said.[2]

Ballistics and aerodynamics were basic to the station's work, and members of the division were involved in nearly every project. "That's why I think we had a little problem," said Franklin H. "Frank" Knemeyer, an early member of the division. "Did they belong broken down into the development departments or did you go to a central group that did the work?"[3] For some customers, the answer to that question was to hire away Ballistics Division employees, and many of the most creative and knowledgeable ballisticians moved on to outstanding careers elsewhere on station. Influential China Lakers who began their NOTS careers in the Ballistics Division included Knemeyer, Highberg, Dr. William R. "Duke" Haseltine, Albin Fojt, Judson "Jud" Smith, Dr. Marguerite "Peggy" Rogers, Ed Winkel, Leroy Riggs, Leroy L. Doig, Jr., Robert J. "Bob" Stirton, Robert G. S. "Bud" Sewell, and William B. "Bill" Porter.

In that company of accomplished ballisticians, Haseltine was one of the most colorful and knowledgeable. Recognized as one of the world's experts in exterior ballistics, he shunned administrative responsibility, preferring to work alone. So intense were his powers of concentration that he burned out many a coat pocket by absentmindedly depositing his pipe therein as he paced the corridors of Michelson Lab. When his blackboard filled up with his scribbled calculations, he'd simply change the color of the chalk and keep going. The entire station knew that he was the ultimate authority on ballistic and aerodynamic problems, but others in the division were nearly as expert.[4] "Haseltine was probably one of the outstanding ballisticians in the country, and you had Albin Fojt who was a good understudy in theoretical ballistics, and you had Jud Smith," said Knemeyer. "If you wanted to get a quick answer, you'd go to Jud and he'd give it to you. Three weeks later, then Albin would come along and give you the final answer. They weren't much different, but at least you had a good verification."[5]

Like the Ballistics Division, the Chemistry Division began in a Quonset hut in 1946, then moved to a Stran steel hut that seemed luxurious by comparison. By the mid 1950s, the division had 20 well-equipped laboratories, a specialized glass-blowing shop, and a large stock room of its own, with approximately 50 scientists working on analytical, physical, inorganic, organic, and combustion and detonation studies aimed primarily at adding to basic understanding of propellant and explosive chemistry. The studies of the chemistry of propellants and explosives—energetic chemistry—had numerous practical applications in the nation's weaponry. Thompson himself singled out propellant research as

U.S. Navy photo LHL 228158

Former members of the Ballistics Division at a 1 June 1974 retirement party for Horace Newkirk.

In front from left are Czerna "Peggy" Flanagan, Judson Smith, Albin Fojt, William B. Porter, Newkirk, Rodney H. Lubben, William R. Haseltine, Franklin H. Knemeyer, and Leroy Riggs. In back from left are Arthur G. New, Larry Delaney, Harold "Punky" Washmuth, Wallace H. Allan, Robert J. Stirton, Kenneth Burke, Gene Younkin, Elaine Jenny, Ray Van Aken, Nancy Seeley, Leroy L. Doig, Jr., Everett Jenny, and Dr. Ivar E. Highberg.

an area "in which I think the foundational work of the Station has been most effective." This success was possible because of the close working relationships at China Lake. "Engineers in development were being fed a stream of new information on combustion mechanisms, new materials, flame phenomena, problem-solving, and new ideas at close range," said Dr. William S. "Bill" McEwan of the Chemistry Division. "They did not have to wait until that information was boiled down and published in some scientific journal that they would very likely never see or read. They could come down and talk to the authors."[6]

Courtesy Dr. William S. McEwan

China Lake scientists in Dr. William S. McEwan's back yard circa 1950 with organic chemist Dr. Neville V. Sidgwick of Oxford University.

Seated from left are Dr. Gilbert B. L. Smith, head of the Chemistry Division; Dr. L.T.E. Thompson, technical director; McEwan; and Sidgwick. Behind them from left are Dr. Ronald A. Henry; Dr. Donald S. Villars; D. Ted McAllister, head of the Editorial Branch, Technical Information Division; Lohr Burkhardt; Dr. Edward St. Clair Gantz, head of the Analytical Branch, Chemistry Division; Dr. John H. Shenk, head of the Research Department; Dr. Robert W. Van Dolah, head of the Organic Branch, Chemistry Division; Dr. A. L. Olsen, head of the Physical Branch, Chemistry Division; Dr. Christian T. Elvey, senior research scientist, Research Department; Dr. Sol Skolnik, head of the Organic Chemistry Division; and William A. Gey.

Several problems solved by Dr. Fred Ernsberger, an alumnus of the Y-12 Electromagnetic Separation Plant at Oak Ridge, were representative of the important role the Chemistry Division played in rocket development. Using both theory and carefully developed experiments in physical chemistry, Ernsberger examined the diffusion of nitroglycerin from the propellant for the Mighty Mouse rocket to the inhibitor wrapped on the outside of the propellant charge. He found that the solubility of nitroglycerin in cellulose acetate made that wrapping material unsatisfactory in extended storage. When he replaced the cellulose acetate with a new formulation of ethylcellulose, a satisfactory shelf life resulted. Ernsberger also developed equations to solve a problem with H-9 propellant. McEwan himself was responsible for the research leading to plateau- and mesa-burning propellants—revolutionary new types of propellant that combined high burning rate with relatively low temperature sensitivity and that gained their names because plots of their burning rates against pressure on logarithmic coordinates took the form of mesas or plateaus. Ernsberger's and McEwan's studies made possible the development and success of several families of solid propellant.[7]

A smaller part of the Research Department, the Mathematics Division began with just three consultants in Pasadena's Physical Science Division. By 1955 the division had grown to nearly two dozen mathematicians specializing in applied mathematics, statistics, and computing, with the computing tools at hand evolving during this era from calculators through small, specialized research computers into massive computers essential to the RDT&E process. The division supported the technical organizations at NOTS by providing advice on sampling techniques and data evaluation, experimental studies of heat flow in rockets, analyses of fire-control and guidance problems, analyses of propellant extrusion tests, and other services calling for mathematical skills. The 1953 *Statistics Manual* by Edwin L. Crow, Frances A. Davis, and Margaret W. Maxfield became a minor classic in the world of statistics, where its users valued the book's practical approach to experiments and sampling techniques.[8]

The youngest research group at NOTS was the Physics Division, which began as a small section divided between the Physical Science Division at the Pasadena Annex and the Applied Science Division at China Lake and which became a full-fledged division at China Lake in 1950. By 1955 the division had about 40 physicists. In the solid-state physics laboratory, researchers studied basic properties of conductors, semiconductors, and insulators. Employees in another specialized laboratory focused on the behavior of metals under impulsive loads, work that directly applied to the development of explosives and warheads. In the hyperballistics laboratory, researchers pursued penetration studies. The optics group measured and computed electromagnetic properties of flame and characteristics of visible and infrared light. Finally, the division's model shop provided the tools needed for fabrication of the special apparatus needed for the various physics programs.[9]

The spirit of the station's academic origins lingered in the Physics Division, where basic science was pursued to an extent unusual for a military laboratory. One of the most theoretical of the Physics Division's researchers was Dr. Fred T. Rogers, Jr., who came to the station in February 1949 as a research associate. His wife, Dr. Peggy Rogers, was a fine researcher in her own right who frequently co-authored papers with her husband. Both had received Ph.D.s in physics from Rice Institute in Houston, Texas. The couple had married in 1936, with their first jointly written research paper, "The Energy-Range Relations for Deuterons, Protons, and Alpha Particles," published in 1938. After a year of post-doctoral research as an assistant in astrophysics at the Yerkes Observatory of the University of Chicago and the McDonald Observatory of the University of Texas, Fred Rogers pursued an academic career. In 1948 he was appointed a research physicist at Oak Ridge National Laboratory. The couple moved to China Lake the following year. Peggy Rogers went to work in the Exterior Ballistics Branch, and in August 1950 Fred Rogers became head of the Physics Division.[10]

Dr. Fred T. Rogers, Jr., at the University of South Carolina circa 1955

Dr. Hugh Hunter, who was associate head of the Physics Division before he moved on to other leadership positions, described Rogers as "a free-wheeling physicist who assumed that he was supposed to do what he wanted to do and he did just that. He began to work on really abstract problems that we wouldn't begin to think of defending today." One such study was of convective flow through a column of sand, an experiment that used the radioactive isotope Phosphorus 32 and that Hunter said Rogers conducted "just because it looked interesting."[11] That drive toward pure research went further than NOTS intended to go, and when the University of South Carolina offered Rogers a position as head of its Physics Department in 1953, he took it.[12]

High-Flying Research Project

In keeping with Thompson's belief that the station's excellent scientific personnel must have the freedom to pursue certain research endeavors on their own initiative, NOTS began its study of the upper atmosphere primarily because of the interests of two of its employees, Dr. Chris Elvey and Dr. Franklin E. Roach, who were wartime research associates at Caltech under an OSRD contract. Both men transferred to NOTS in 1945. Elvey had earned his doctorate in astronomy from the University of Chicago and had worked as an astrophysicist at Chicago's famed Yerkes Observatory and the McDonald Observatory of the University of Texas, where he collaborated on a photoelectric study of the light of the night sky with Roach, who had also earned his Ph.D. at Chicago. During World War II Roach had directed an extensive program in explosives research for Project Camel, the code name for NOTS' work on non-nuclear explosive components of the atom bomb as part of the Manhattan Project. After the war, Roach moved to NOTS Pasadena and continued to work in explosive materials.[13]

At first both men applied their expertise to practical problems in explosives and ballistics, but with an expansion of the Aerophysics Section, which the Research Department had established in September 1946, the two scientists found a niche that better suited their interests. The section's first employee was Edward V. Ashburn, whose interest in atmospheric phenomena rivaled that of his supervisors. Ashburn had been a forecaster and weather researcher for the U.S. Weather Bureau, working during World War II on an aircraft icing research project for the Army Air Corps and the National Advisory Committee for Aeronautics (forerunner to NASA). As Roach and Elvey began their expansion plans, Ashburn was already providing support for a high-flying endeavor known as Project Apollo.

This pioneering study of the upper atmosphere started when the U.S. Army Air Corps (a predecessor to the Air Force) agreed to support an ONR request for B-29 bombers to carry scientific equipment to high altitudes to measure cosmic, solar, and sky phenomena. The Air Corps agreed to provide aircraft, officers, and flight crews. The Navy's part of the project encompassed maintenance, fuel, and other logistic aspects of the flights, as well as the scientists to conduct the studies. The station had an ideal combination of assets to support Project Apollo: excellent flying weather, the long runways needed for B-29 landings, a hospitable organizational environment, and interested scientists with strong links to a community of astrophysicists at universities across the nation.[14]

Aircrew members for Project Apollo were assigned to Wright-Patterson Air Force Base, Dayton, Ohio. A unit of four officers and 12 airmen modified three B-29s to accommodate scientific equipment, then accompanied the rebuilt aircraft to China Lake in September 1946. Charles D'Ooge, project liaison officer from ONR's Pasadena office, also came to the desert to shepherd ONR interests.[15] During the nearly four years the Project Apollo B-29s were stationed at Armitage Field, they flew 268 missions, from the equator to the Arctic Circle, for an estimated 600,000 miles at altitudes of up to 40,000 feet.[16] The flights accumulated data to support research conducted by several participating scientists, who then authored an extensive list of scientific publications. As Ashburn pointed out, NOTS and the Navy benefited by receiving widespread recognition in the scientific community.[17]

By July 1950 Project Apollo had reached its main research goals and was canceled on the recommendation of the Chief of Naval Research.[18] An unexpected consequence of the experiment was China Lake's Sierra Wave Project, conducted between November 1950 and October 1952 and designed to contribute to understanding of the meteorological conditions contributing to the Sierra Wave effect. This project came about after one of the Project Apollo pilots flying out of China Lake gave the first report of an experience with the Sierra Wave, a reaction of upper-air winds as a weather front approaches the steep eastern scarp of the Sierra Nevada. The effect, with its rising winds and distinctive lenticular clouds, has proved irresistible to glider pilots, and many national and world soaring records have since been set in the skies over Inyokern Airport.[19]

After cancellation of Project Apollo, the station's involvement in upper-atmosphere research continued. Elvey and Roach had succeeded in expanding direct involvement in ONR-funded studies of the upper atmosphere and had undertaken joint supervision of the Aerophysics Section. Elvey soon took on other management duties, becoming acting head of the Research Department in 1948 and senior research scientist in October 1949, but he retained an avid interest in night-sky studies. The Astrophysics Section expanded to become

Sierra Wave effect, looking south along the Owens Valley, California.

two branches, one in Pasadena under Roach and one in China Lake under Ashburn, and the station became for a short time one of the nation's foremost centers for the study of atmospheric physics.[20]

Adopting the term "airglow" to designate the type of night-sky light they were studying, Elvey and others in the group set up discharge tubes in Michelson Laboratory and began painstaking spectrographic measurements to determine the character of the light emitted. They soon discovered that hypersensitive photographic plates exposed for a week or more yielded distinct features of the airglow spectrum. To accomplish the necessary exposures, the team enlisted the aid of the Michelson Lab security guards, who would check on the apparatus every hour on weekday nights and over the weekends.

In another part of the study, Roach and a small team began collecting and analyzing photometric data useful in isolating infrared-emitting light in the upper atmosphere. Several observatories in the U.S. and Europe helped by collecting data. Of most immediate use were observations the station's astrophysicists made during the dark of the moon at Palomar Observatory and at Cactus Peak, an instrumented cinder cone located near NOTS' northwest boundary. Ashburn had the related task of determining the density of the upper

Spectrograph to measure features of the airglow spectrum.
Research Department employee Harold Turner uses the apparatus in September 1950.

atmosphere by using photoelectric photometers to measure sky brightness from sunset until the last trace of twilight had disappeared, then using data from these observations to compute the atmospheric density of sunlight.[21]

Numerous NOTS publications resulted from these endeavors, including 17 reports in 1950 alone.[22] Evidence of the station's prominence in this field was a May 1950 meeting that brought a distinguished group of U.S. and European scientists to China Lake. The ONR representative reported comments from several participants that "it was the best scientific meeting of its size that they had ever attended."[23] The year 1950 represented the height of the station's upper-atmosphere research program, but the Physics Division continued a more limited high-altitude program, with notable contributions later made by Dr. Pierre Saint-Amand, who commented that "it turned out that there was a good reason for it all," in that the study of chemical reactions in the upper atmosphere set the stage for China Lake's pioneering space-technology work, particularly on re-entry problems, that occurred in the 1960s and 1970s.[24]

The night-sky studies were also partially responsible for the 1948 construction of the station's highest, coldest, and most remote laboratory—a small facility perched near the bleak summit of California's White Mountain, 165 miles by road north of China Lake. The White Mountain Research Station was designed as a high-altitude observing station closer to home than the two then in existence (in France and Colorado). Prominent among those urging construction of the site were Elvey, Dr. Ira S. Bowen, and Dr. Carl D. Anderson, winner of the 1936 Nobel Prize in physics. In addition to high-altitude projects planned by Anderson and other university researchers, NOTS researchers planned to use the station to conduct night-sky observations, studies of the infrared spectra of the sun, and experiments with explosions at reduced atmospheric pressure.

In August 1948, with ONR approval for the project, a NOTS Public Works crew began constructing the necessary facilities. By early fall the crew had blasted and bulldozed out a narrow road linking State Highway 47 at Westgard Pass with the site of the highest planned outpost 12,242 feet in elevation and 19 tortuous miles beyond the pass. At times the new road followed an old wagon trail and at times it gouged out a route along a path blazed by the U.S. Forest Service. The road was intended for passenger cars, but drivers of such vehicles found the long, steep grades and hairpin turns daunting.

True to his earlier prediction, Anderson found the station useful. He and Robert Leighton used a cloud chamber at the White Mountain site to obtain the world's first pictures of V particles (unstable cosmic-ray particles so named because their forked tracks in a cloud chamber resembled the letter V). Other researchers making good use of the research station included Dr. Robert B. Brode, who put in a large mass spectrometer; and UCLA's Robert Leonard, who carried out a year's study of the attenuation of sound waves.[25] But the station's direct involvement diminished rapidly. By late 1950 White Mountain's


U.S. Navy photo NP/45 18323

White Mountain Research Station near Westgard Pass, December 1948.

usefulness to NOTS had deteriorated to that of a remote weather station. That October the station turned the facility over to the University of California at Berkeley under an ONR contract, with support from the National Science Foundation and the Rockefeller Foundation for Medical Research.[26] Later NOTS found the facility useful for infrared-seeker targeting tests.[27] Today Berkeley still operates the research station, and China Lake's role has been largely forgotten, with the main significance perhaps as an illustration of the breadth of NOTS' early research studies.

Aircraft Fire-Control Systems

Pioneering scientific expertise also existed in the Aviation Ordnance Department, which numbered among its employees several who worked on fire control and bomb directors even before NOTS was founded. These specialists included Dr. Eugene P. Cooper from the Franklin Institute, Joseph H. "Joe" Hibbs and McLean himself from the Bureau of Standards, and Dr. I. Henry Swift, Dr. Albert G. "Al" Hoyem, Dr. Lewis E. Ward, and Robert B. Allen from the State University of Iowa. These men converged at NOTS in 1945–1946 to form the nucleus of what became a department dedicated to aviation ordnance work. Their early work focused on development and refinement of the electromechanical integrators and gun sights that allowed unguided bombs and rockets to hit their targets. By the early 1950s, NOTS was also creating innovative fire-control systems, radars, and bomb directors.

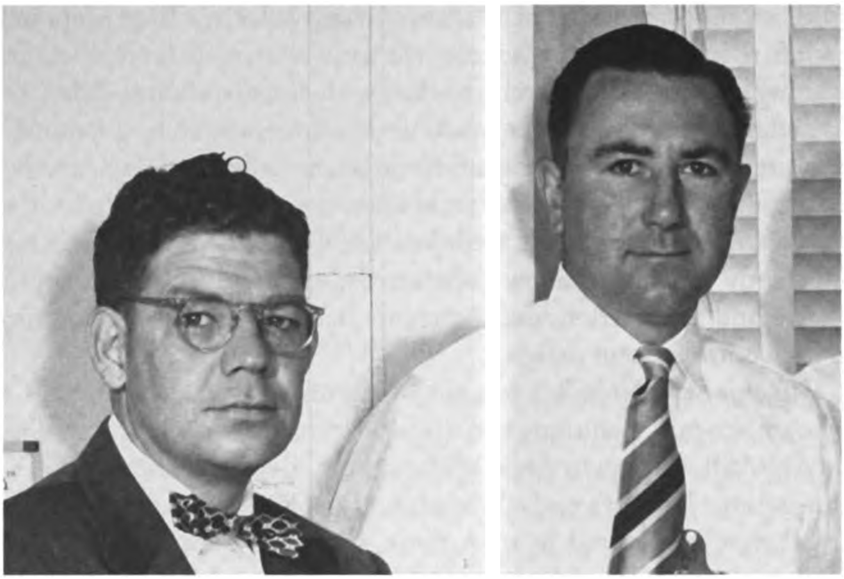
The Navy relied heavily on NOTS range and evaluation facilities for testing bomb directors. The first such system to be evaluated at China Lake was the experimental Bomb Director Mk 2, designed jointly by Norden Laboratories Corporation and Bell Telephone Laboratories. The station built on its knowledge of the Mk 2 to develop improved range instrumentation and flight evaluation procedures for the follow-on Mk 5 and its later incarnation, the Norden-developed AN/ASB-1. Another system for which the station assumed trouble-shooting responsibility in 1945 was Bomb Director Mk 3, as designed by the Bureau of Standards earlier that year. The system represented a new versatility in that it could guide pilots armed with rockets as well as bombs. By 1949 the Mk 3 was in production. Flight testing at NOTS continued until late 1952 to help solve production problems encountered by the Naval Ordnance Plant, Indianapolis (NOPI), and to help train fleet pilots in the system's use.[28]

During the course of testing these systems, the station developed innovative measuring systems that were perpetuated at China Lake and elsewhere. In one such technique, devised in 1949, employees of the AOD Evaluation Division came up with an innovative way of measuring wind velocity. They proposed that an aircraft release a puff of smoke at the same instant it fired a rocket. The free-floating smoke would then be tracked with cinetheodolites. Both the smoke puff and the oncoming rocket would also be documented by a remotely controlled camera located at the center of the target, as well as by other cameras along the flight path. By adopting this technique, the station was able for the first time to obtain a photographic record of the flight path of an attacking aircraft sufficiently reliable to allow accurate determinations of skid angle, angle of attack, and acceleration, measurements that needed to be taken into account in fire-control system design.[29]

Bomb Director Set AN/ASB-1 was one of several systems tested at NOTS that used the smoke-puff technique to help with the evaluation of test results. Tests of the AN/ASB-1 began in April 1950, when a "flying workshop" PB4Y-2 arrived on-station. By year's end, three prototype sets were undergoing test at NOTS and were being used to train those who would use the system in combat. The station set up and operated Project Atlas, which Newt Ward praised as "the first and at that time the only school for instructing maintenance and operation personnel."[30] Over the following five years, Project Atlas trained more than 200 fleet personnel in the theory, maintenance, and use of the new bomb director.[31]

The AN/ASB-1 was designed to accomplish automatically some of the tasks previously required of the pilot. The system's initial performance left much to be desired, with a few unreliable components contributing to the failure of the PB4Y's first bombing runs over B-1 Range. Within two years, more than 1,000 drops occurred from the PB4Y alone. By mid-1953 the PB4Y was being used primarily to test production equipment, to train bombardiers and maintenance men, and to develop techniques in radar photography. Tests of the AN/ASB-1 had shifted to two AJ-1 aircraft, with each series of flights designed to investigate a specific weakness. That systematic approach led to gradual accuracy improvements by Norden Laboratories and other firms. The system successfully passed its first operational readiness test in late 1955.[32]

Building on NOTS' success in AN/ASB-1 evaluation, BuOrd in late 1955 assigned the station part of a broad RDT&E program in support of the Navy's heavy-attack mission. From this program emerged AN/ASB-7 in 1955 and AN/ASB-8 in 1956. Bomb Director Set AN/ASB-8 was an all-weather, air-to-ground system that provided for weapon delivery from horizontal, dive, toss, loft, over-the-shoulder, or lay-down attacks; and that could be used to deliver bombs, rockets, missiles, or mines. In a concurrent effort, the station worked on



Courtesy Elva Younkin

Dr. I. Henry Swift and John Gregory.

lighter bomb directors for small attack aircraft, designing Bomb Director EX-1 (renamed Mk 9 in 1954) specifically for use with single-seat aircraft. Starting in 1953, NOTS guided Bomb Director System Mk 10, essentially Mk 9 coupled with Radar System AN/APG-53, from conception through preliminary development and prototype production. Again, this system was intended for flexible toss delivery of special weapons (atom bombs) and conventional bombs from light-attack aircraft. The Mk 3 Mod 3 system replaced the Mk 10 in 1956 when the A4D-3 aircraft for which Mk 10 was intended was replaced by the A4D-4. A later version of Mk 10 would resurface by the end of the decade in the station's pioneering Shrike missile, with the follow-on Weapons Delivery Computer CP-741/A seeing action in Vietnam.[33]

In addition to work on designing bomb directors and redesigning fire-control systems that other organizations sent to China Lake for trouble-shooting, NOTS developed two major fire-control systems of its own, Aircraft Fire Control System (AFCS) Mk 8 and AFCS Mk 16, which BuOrd assigned to China Lake in late 1949 and early 1950.

Today the Mk 8 radar-controlled, all-weather fire-control system is remembered primarily as a motivation for Bill McLean to design his pioneering infrared-homing missile. McLean himself said he designed Sidewinder to avoid the Mk 8.[34] Ward recalled that when BuOrd sent the station a requirement to develop an all-weather fire-control system, McLean wrote back, "It's not worth doing." According to Ward, the bureau's answer was "We heard you. Do it."

McLean then assigned the project to John H. Gregory, head of Development Branch 4, and Gregory's group began working on the system on the third floor of Michelson Lab.[35]

One of the third-floor engineers was James J. "Jim" McLane, who showed up at NOTS in June 1951 as a summer intern, then returned the following summer after earning a degree in electrical engineering from the University of Wisconsin. At first McLane thought Mk 8 was some sort of aircraft fire-extinguishing equipment, but he learned that the system, "a rather ambitious program for the technology of those times," was intended to improve the aiming accuracy of rockets, guns, and bombs. The attempt to encompass fire control for many types of weapons in one system was an ambitious undertaking. Small, rugged electronic computers were still on the horizon, and the Mk 8 accomplished its computing with mechanical gearboxes and servos, much like an elaborate adding machine. "To put that kind of stuff aboard airplanes and try and compute as carefully and as accurately as you had to for the ballistics of those bombs was a pretty ambitious thing to do," said McLane.

He recalled that Mk 8 was one of the first major systems to use printed circuit boards. These early boards, each about 12 inches by 2 feet, were huge by today's standards, with each board containing hundreds of connections. At

U.S. Navy photo NP/45 55200, courtesy Jim McLane

James J. "Jim" McLane assembling a data converter used in the evaluation of fire-control systems, 1953.

Breadboard layout for an experimental fire-control system, August 1954.

Working on the system are Billy Davis (left) and another employee of Development Division 1, Aviation Ordnance Department.

first the boards were soldered at too low a temperature. "There were hundreds and hundreds of vacuum tubes and five or six big gear boxes and all that stuff grinding away doing this computing, and all these solder joints were failing," McLane said. "What we wound up doing was tearing that computer totally apart and by hand going over all of the printed circuit boards and resoldering them by hand before we could make the thing finally work. . . . Oh, it was a horrendous job."[36]

Shortly after the Mk 8 development began, the bureau agreed to fund the interim AFCS Mk 16, which Henry Swift and the members of Development Branch 1 were creating on the fourth floor of Michelson Lab.[37] The rugged Mk 16, which incorporated the first use of magnetic amplifiers for analog computing, turned out to be the lightest, least expensive, and most accurate fire-control system this country had ever produced. The magnetic amplifiers used variations in voltage to accomplish what could previously be done only with vacuum tubes, which not only frequently failed to operate but also generated too much heat when they did work. Development went well, and the system reached the test-flight stage in 1951.

Scarcely had the Mk 16 begun production when Swift and his branch invented a way to perform the same calculations with components a third as large, a third as heavy, and costing only a third as much. That new system was the EX-16, which had as its brain the NOTS-invented Computer Mk 101 with its revolutionary logarithmic computational method to improve accuracy. This method made it possible for the computer, which could only add, to solve necessary multiplication and division problems. Mk 101 received input signals that had been converted into their logarithms, then added the logarithms to yield a signal, the logarithm of the product of the original signals. The computer also used direct current instead of alternating current, thus eliminating phasing and harmonics as sources of error and greatly simplifying the instrumentation and control operations required in production. The magnetic amplifiers, resistors, and semiconductor circuits of the new system also made it far lighter, more versatile, cheaper, and easier to build and maintain than its vacuum-tube-powered predecessors had been.

Initial flight testing of the air-to-air gunnery mode in the F9F-5 Panther included 89 flights completed in April 1954, during which the computer operated for about 150 hours with no failures other than a defective diode.[38] By the following year, Mk 16 systems had been installed in 20 squadrons, and EX-16 was starting pilot production at NOPI.[39]

Even as NOTS accomplished its goals for fire-control systems, station leaders became unwilling participants in a long-festering struggle between BuAer and BuOrd. Just as with the missile cognizance dispute, the increasing complexity of the systems under development meant that a new level of cooperation or consolidation was imperative. In spring 1952 the Naval Inspector General's office found that China Lakers working on fire-control systems were not as familiar as they needed to be with the design characteristics of the BuAer aircraft on which these systems could be used. "In view of the fact that a fire-control radar and an airplane must be designed as a complete system," the auditors said, "close liaison between the NOTS technical staff and aircraft designers, via BuOrd and BuAer, is mandatory."[40] The station responded that a direct liaison with BuAer, plus "very good liaison direct with the aircraft designer," would help and that "improvement in exchange of information between NOTS and BuAer is highly desired by this Command."[41]

According to then-Captain Paul D. "P. D." Stroop (later a vice admiral), who became deputy chief of BuOrd in December 1954, the BuAer and BuOrd chiefs met for about a year and a half "trying to resolve just this one problem of fire control, and it never was resolved." Stroop commented further that the dispute was one of the problems that later motivated Under Secretary of the Navy William Franke to recommend that the two bureaus be combined.[42]

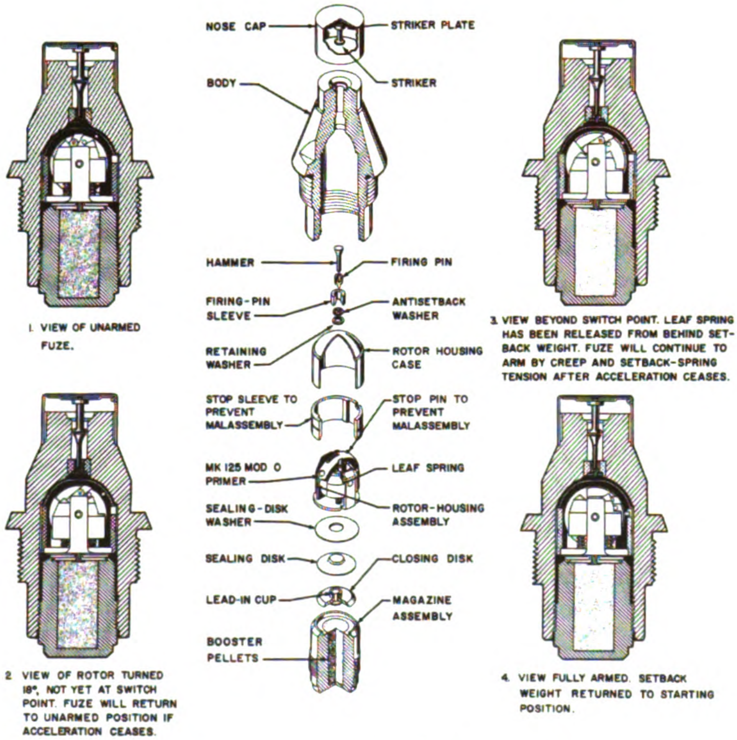
One attempt to resolve the problem came in 1956 when an internal Navy realignment gave BuOrd complete responsibility for solid-propellant rocket motors, with BuAer receiving complete responsibility for aviation fire-control equipment. As part of this realignment, NOPI became the Naval Avionics Facility, Indianapolis (NAFI), and further development of EX-16 was turned over to NAFI, a BuAer organization. However, as McLean commented during the height of the dispute, "No one is able to answer the question as to where the Navy will get fire-control equipment if NOTS is not in this kind of business. There is some indication that the BuAer would like to use NOTS as a contractor for the production and test of fire control systems."[43]

That prediction proved to be accurate, and over the ensuing years, the station's fire-control work evolved to take advantage of increasingly sophisticated technology and to meet the needs of BuAer and its successors. China Lake's solid accomplishments in avionics hardware and software during the era of the Vietnam conflict evolved to today's sophisticated avionics suites—direct descendents of the bomb directors and fire-control systems developed by AOD engineers in Michelson Lab.

Renewed Work on Fuzes

With each new rocket NOTS developed, a new or redesigned fuze was also necessary. In the station's first years, it had worked on all aspects of rockets, including fuzes—a complete-system responsibility that the desert mavericks much preferred to the practice elsewhere of assigning individual components to the engineers, then finding out (sometimes too late for good results) whether the components would work together. In early 1947, however, the bureau had consolidated its fuze work at the Naval Ordnance Lab. From its turn-of-the-century beginnings in the Washington Navy Yard as the Naval Gun Factory, NOL had a proud history of fuze development. During World War II the laboratory's work had expanded into mines and countermines. In 1948 NOL moved its base of operations to White Oak, Maryland, and added an expanded aeroballistics test program in its supersonic wind tunnel.[44]

With these new responsibilities, NOL decided that its plate was too full for it to provide the specialized fuze-development talent necessary to keep up with the demands of the desert rocketeers.[45] In spring 1948 BuOrd asked China Lake to develop a point-detonating fuze for the 2.75-Inch FFAR, Mighty Mouse. But as much as station leaders wanted responsibility for developing the entire



NOTS 872, Rocket Department Technical Appraisal

Inner workings of the Mk 184 Mod 0 fuze.
Mk 184 was a member of a NOTS-developed family of acceleration-armed fuzes that began with the Mk 176 fuze for the 2.75-inch Mighty Mouse rocket.

rocket, they were reluctant to reactivate a full-scale fuze development program for a single project. After much deliberation, BuOrd agreed in December 1948 that NOTS could reestablish its fuze section on a permanent basis and could maintain at least one fuze project at all times. In addition to developing fuzes for the rockets for which it already was responsible, the station would be expected to test fuzes developed at other Navy installations.[46]

Applying lessons learned from several watch companies, C. Robert "Bob" Olsen, head of the Explosives Department's Fuze Section, developed Mk 176, the 2.75-inch rocket's first fuze and a marvel of miniaturization in its day. The Mk 176 employed a delayed-action device designed to penetrate an aircraft's outer skin, then detonate within the aircraft structure. Ellis recalled:

> We had some B-29 wings stood up on end out at K Range, and we'd fire those rockets with boosted velocity to get the equivalent to an aeroplane firing at these wings. There was a bunch of military there to see one of the tests. Here's this B-29 wing. There's a hole in it where the rocket went in. They went out

> and looked at it and said, 'Well, that's not much.' Then they went around to the back side, and the whole back skin was gone.[47]

When the Research Board got together in late 1949 to summarize the technical program, the resulting report identified the Mk 176 success as "in line with the general policy that responsibility for a weapon development should include all components." In an oblique reference to NOL, the report added that "close liaison with agencies active in the development of rocket proximity fuzes is considered to be imperative."

The Mk 176, which entered mass production in 1952, provided evidence that fuze-development work fitted well into the China Lake philosophy of total-system development.[48] NOTS had earned the right to develop its own fuzes when the situation warranted it. Over the following decade, China Lake-developed fuzes appeared in many of the station's rockets.

Building a Better Mouse

As NOTS made gratifying progress in the fuze area, other components of the new folding-fin rockets were also taking shape. By April 1949 NOTS had nearly completed the experimental design of a 2.0-inch folding-fin rocket. But with the outbreak of the Korean conflict, work on the 2.0-inch rocket was suspended so that the station's experts in small-caliber rockets could concentrate on getting the 2.75-Inch FFAR ready for service use.[49] Design decisions for Mighty Mouse were of necessity accompanied by extensive static and field tests, as well as modification at one time or another of nearly every component in the rocket.[50] Close communication was essential, involving laboratories, test ranges, and specialists in simultaneous work on launcher, fuze, warhead, propellant, and fire-control system.

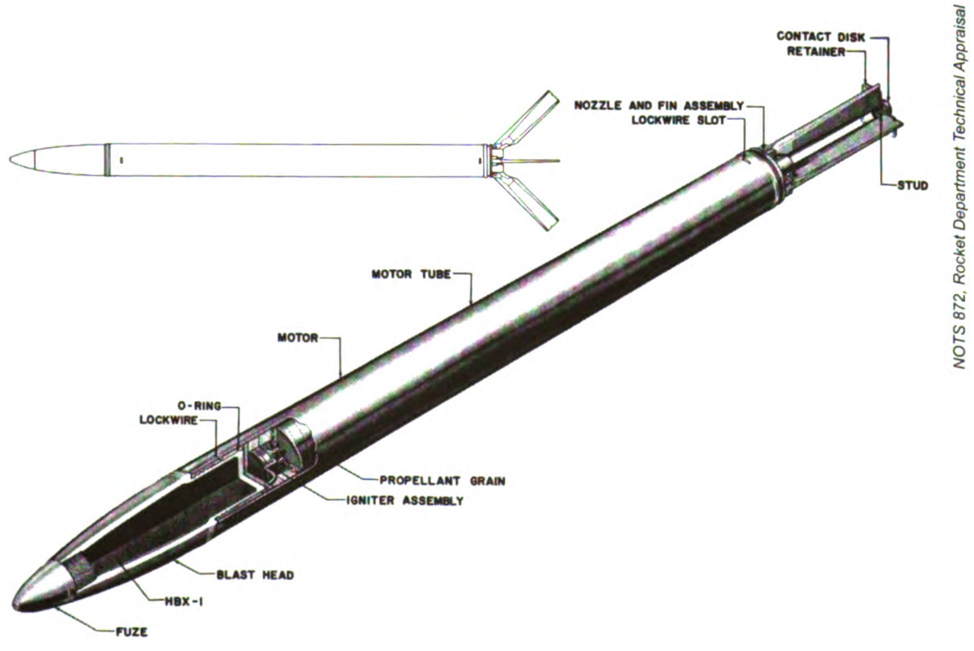
The rocket required testing and checking to make sure tolerances stipulated for the motor-tube manufacturers were being met with enough precision. One area needing new definition was in the design of the small, but crucially important, seals that protected the fragile rocket tube. Even with internal-burning propellant, hot gas could—and sometimes did—break through seals and weaken the aluminum tube, particularly at the nozzle end of the grain (the extruded, shaped propellant charge) where the gas was hottest. The problem occurred intermittently, but with a frequency that could not be ignored.

The aft end of the grain was no problem, since acceleration pushed that end against the nozzle. But at the head end, the situation was different. Because the extruded and inhibited propellant grain had to be small enough to allow it to be pushed into the rocket after manufacture, the diameter of the grain had to be slightly smaller than the inside of the motor tube. The pressure of the resulting space had to be carefully controlled to prevent grain failure, especially at low operating temperatures when the clearance was greatest and the grain the most brittle. A chamber in front of the grain accommodated a "tin-can" igniter. What was needed to fill the space was just enough gas flow to allow the pressure outside the grain to equal that inside. Any more or less pressure would inevitably lead to uncontrolled destruction.

After several potential solutions introduced new problems, the FFAR developers came up with what Harold "Pat" Patton described as "little stools," two small rings separated by four small studs that would allow the right amount of gas to get through. These glued-in inserts would be ejected by the propellant gases when the rocket was fired.

After the refined design was successfully fired, the Rocket Department followed established NOTS policy and turned the FFAR over to D&P and its acting head, the dapper Kelvin H. "Kel" Booty.[51] What happened next was a hard lesson in the necessity of effective communication between developers and production designers.

Motors built from the production drawings began blowing up during flight. To fix the problem, engineers needed to get a look at a rocket that had survived



The 2.75-Inch Folding Fin Aircraft Rocket "Mighty Mouse."

a test flight. Numerous neat holes, each 2.75 inches in diameter, in the China Lake playa were evidence that such rockets were available—but retrieving them was another matter. When a digging expedition finally retrieved a rocket, it yielded immediate, obvious evidence of what had gone wrong. Unaware of the purpose for the inserts, D&P engineers had instead stipulated machined ridges and four small holes through which the gas would flow. The problem with that solution, as Patton explained, was that "if you channel [the gas], you've got yourself a very destructive device. . . . So here we had our four bulges—we used to call them Kel's cheeks!"[52]

With the little stools reinstated, the 2.75-Inch FFAR demonstrated promise in subsequent tests. The time had come for the station to do what it could to make sure a reliable rocket would come off the assembly line. Design refinements made manufacture of the 2.75-Inch FFAR more difficult than that of previous rockets, and both the Rocket Division and the D&P Department studied every part of the rocket to simplify design, relax tolerances, find substitute manufacturing methods and materials, and reduce the number and complexity of components.

In August 1948 the station hosted a symposium requested by BuAer and authorized by BuOrd. This meeting, the first of its type at NOTS, was designed to acquaint aircraft manufacturers with the characteristics of the new rocket. Attendees included representatives from Douglas Aircraft Company, Grumman Aircraft Engineering Corporation, McDonnell Aircraft Corporation, North American Aviation, Inc., and Lockheed Aircraft Corporation. The meeting signaled the beginning of many such exchanges of information.[53]

The Navy intended Mighty Mouse to be a prime weapon against hostile bombers, the primary nuclear threat before intercontinental ballistic missiles became available. The Air Force also geared up to use Mighty Mouse on the North American F-86D Sabrejet with a 24-round package that popped out of its belly; the Northrop F-89D Scorpion, the nation's biggest interceptor, with 104 rockets to be carried in two wingtip pods; and the Lockheed F-94C with 24 launch tubes that hinged out in the nose, plus two 12-round wing pods.

Station involvement during the production phase continued to be essential. Patton remembered that one Lockheed ordnance designer, faced with venting the hot rocket exhaust in the crowded nose area of the F-94C aircraft, decided, despite the objections of the NOTS Rocket Department, to simply close the rear of the rocket's tube. "Photos of rockets emerging from the aircraft in flight bore out our worst predictions—head over heels is an apt description," Patton said.[54] Jim Wiegand, who became head of the Explosives Department's

Propellants Division in 1949, said the station "had to put pressure on the companies to produce a higher quality of tubing with closer tolerances."[55] At the request of the BuOrd Manufacturing Division, NOTS engineers visited metal-parts manufacturers, as well as the warhead and assembly facility at the Naval Ammunition Depot at Shumaker, Arkansas. Experts at CLPP worked even more directly with the Naval Powder Factory at Indian Head, Maryland, to ensure formulation and manufacture of acceptable propellant grains.[56]

Such communication was doubly important, since changes in rocket design required careful coordination with the developers of BuAer's new interceptor aircraft. Further pressure to hasten the manufacture of a standardized Mighty Mouse came from the Air Force, which in June 1949 asked for an immediate consignment of 3,500 rounds to conduct its own FFAR evaluation program. As a consequence, in October BuOrd essentially froze the FFAR design, agreeing to accommodate only a few minor changes.[57] In November NOTS transmitted project plans to BuOrd, and the following July experimental production of the 2.75-Inch Rocket Motor Mk 1 Mod 0 began.[58]

That transition to manufacture was "one hell of a stage," according to Patton. For the rocket to work reliably, manufacturers who understood the need for care were crucial. The necessary limited gas flow could be achieved only if the O-ring and lock-wire grooves machined into the steel of the nozzle met precise tolerances. In the haste to produce the missile, however, the bureau's Manufacturing Division (Ma) hired a washing-machine company to manufacture the nozzle. Patton remembered that an official at Ma told him about watching a lathe operator at Easy Washing Machine:

> [T]hey were running these things on an automatic lathe, and they were cutting these two grooves, and he said the guy was taking it out of the lathe and tossing it into a steel tray. You could imagine what would happen to these delicate groove edges, and the last thing you want in an O-ring is a notch because that aims the gas right at one spot, and you're in trouble. And the last thing our lock-ring grooves could stand was a dent so that you couldn't roll the lock wire in.[59]

Hack Wilson knew of the 2.75-inch rocket's pre-production problems from his perspective as an employee of Re2b, the Fuze Research Development Section of BuOrd's Ammunition Branch. He remembered thinking that "they just threw the drawings and specifications for the 2.75 over the fence." In Wilson's opinion, such actions delayed production of Mighty Mouse by at least two years when the dismal results of proof firings led to a second cycle of development, beginning in early 1950.[60] China Lake would encounter ill-informed design and production decisions numerous times over the years to come, with NOTS and its successors called in to fix flaws that would not have occurred if in-house production engineers had issued the initial specifications.[61]

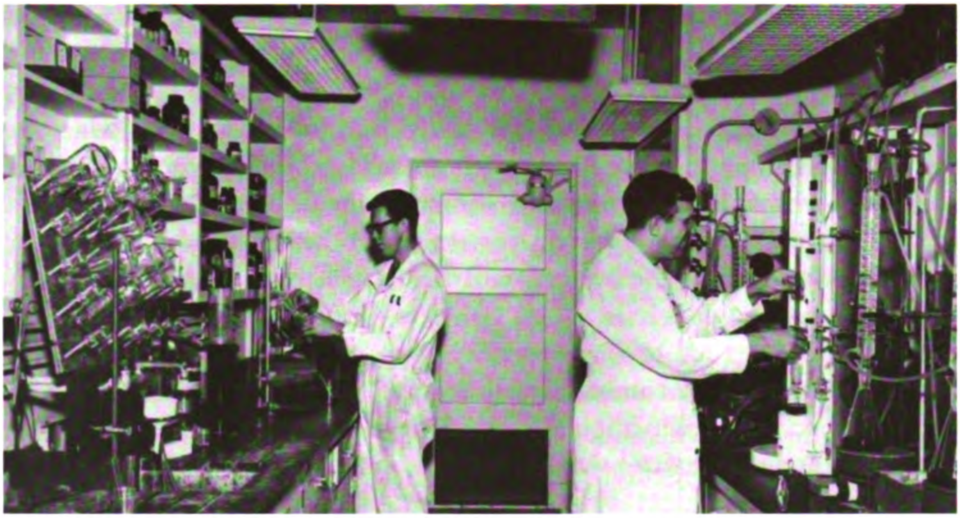
Propellant Innovations

Transition to 2.75-Inch FFAR production revealed persistent problems with the propellant grain. To correct these problems, NOTS propellant developers experimented with new formulations at the station's new CLPP propellant manufacturing plant. At first H-9, a relatively cool, slow-burning propellant, seemed excellent, but under extended storage, nitroglycerin and the stabilizer DPA reacted to give off gaseous products in such quantity that internal cracking destroyed the structural integrity of the charge. Again the Chemistry Division demonstrated the benefits of close teamwork as Ernsberger demonstrated that replacing DPA with a decomposition product from DPA's reaction with nitroglycerin would lower the rate of gas production enough to eliminate the cracking.[62] Experiments showed that the best alternative involved a chemical discovered by Dr. Linus Pauling in experimental laboratory studies at Caltech during World War II. Station employees began formulating, developing, and testing propellants designed for a shelf life of at least 36 months.[63]

In exactly six months China Lake chemists and propellant engineers had evaluated the initial 1,000-pound lots of N-4 made at Picatinny Arsenal and had extruded and inhibited test grains for the FFAR. By July 1950 the Naval Powder Factory, working closely with NOTS on all aspects of pilot production, evaluation, and control, had processed the new propellant into grains and test-fired them. Production at the Radford Arsenal began in late 1950, with the Sunflower Ordnance Works at Lawrence, Kansas, subsequently also producing N-4 grains. The grains saw their first use in service rounds in mid-1951. That rapid development could not have happened without the station's new small-scale propellant-development facilities.[64]

By the closing months of 1950, most N-4 specification problems had been solved, and NOTS propellant researchers and developers turned their attention to other propellants. In late 1950, the first 250 rounds of the 2.75-Inch FFAR, incorporating N-4 grains, were manufactured at the Naval Ordnance Plant, Forest Park, Illinois.[65] China Lake propellant developers began to study a perplexing problem, the solution of which had the potential to greatly improve the performance of all solid-propelled rockets.

Because rocket performance was dependent on propellant temperature at the time of ignition, performance could be predicted only if that temperature could be controlled. Solid propellants were inherently poor



Chemical laboratory for propellant investigation.

thermal conductors, with their ignition temperatures varying as a result of the conditions under which rockets were stored, loaded, and fired. Precise prediction of a rocket's trajectory was next to impossible. Propellant designers also had to find a way to meet a requirement that a rocket operate at all ambient temperatures from -65 to +165 degrees Fahrenheit, a temperature range necessitated by atmospheric conditions as the rocket left its host aircraft. An igniter adequate to stir the lethargic propellant at a cold temperature would blow up the motor at higher temperatures.

Station researchers pursued experimental studies to gain a better understanding of ignition phenomena, including the effects of propellant surface area, composition, and pressure response on ignition. A redesigned igniter case incorporating a blowout plug reduced the ignition blast that otherwise might cause the propellant grain to crack under the stress of the first few milliseconds of the ignition cycle.

A search also began for a suitable replacement for black powder as the ignition agent. Early investigations of the British metal-oxidant mixture of potassium nitrate and magnesium led to a dead end when NOTS investigators could find no commercially feasible coating that would inhibit surface oxidation. After further experiments, China Lakers created a controlled mixture of black powder and coated magnesium, which the station used in its subsequent rocket designs.[66]

A NOTS team under Wiegand's direction was also exploring what could be done to make propellants in general less sensitive to troublesome temperature variations. Work leading to the development of plateau- and mesa-burning propellants (so called because logarithmic plots of burning rates against pressure resembled desert tablelands in profile) began in the Chemistry Division, where Dr. Bill McEwan conducted burning-rate studies, which he termed "an absolute necessity for designing solid-propellant rocket motors." Through a study of the burning rate of fine filaments of different metals, he showed that the rate went up in proportion to the thermal conductivity of the metal. That meant that the burning rate of a propellant could be increased by putting aluminum wires in it.

Those findings led to the possibility of a propellant that would have a very high burning rate combined with relatively low temperature sensitivity. Exceptions to this observation explained mesa and plateau phenomena in propellants and opened up a whole new field of double-base propellants. "This was a very valuable adjunct to the science of propellants," McEwan commented later. "With mesa propellants, we could make the burning rate of the propellant and hence the ballistics of the rocket independent of temperature changes."[67]

The December 1950 arrival on the desert of Albert T. Camp brought new brainpower to bear on the problem. Already a recognized authority in the propellant field, Al Camp had a background in research chemistry and safety and production engineering, as well as seven years experience as a rocket-propellant engineer for Hercules Powder Company and the Allegheny Ballistics Laboratory. The station's success in recruiting Camp could be partially explained by the dry climate his daughter's health needed. Whatever his reasons for hiring on, the team working on the temperature-control problem greeted his arrival jubilantly. He set to work applying a variety of ballistic modifiers (materials that controlled the ballistic properties of propellants and reduced their temperature sensitivity) to mesa-burning propellants and soon formulated the promising new propellant designated N-5.

The N-5 program showed, as did so many others, the desirability of having laboratory, testing, and experimental production facilities near one another. The immediate availability of the laboratory-scale manufacturing facility meant that as soon as Camp came up with the formulation for N-5, CLPP could begin turning out small batches. Small-scale development began in March 1951, and free-flight testing in the 2.75-Inch FFAR followed almost simultaneously.

The new propellant had a burning rate that increased with pressure at first, then stopped increasing, actually decreased, and finally increased again. Moreover, N-5 could be directly substituted for its predecessor in existing rocket motors. Most remarkable, in Wiegand's words, was that there was "no change in operating pressure from about 0°F to 100°F, a truly amazing development." This temperature insensitivity would allow an aircraft carrying FFARs to "leave off the temperature correction in the ballistic fire-control system, thus saving weight, reducing complexity, and improving accuracy." Tests of N-5 in the 2.75-inch rocket showed the superiority of the new formulation.[68]

By fall 1952 the N-5 development program was considered complete, and a new grain (Mk 43) of N-5 propellant for the 2.75-Inch FFAR proved so promising that the station asked for an almost immediate changeover to the grain in production facilities across the country.[69] A subsequent NOTS publication pointed proudly to the development of N-5 as "from the ballistics point of view the most significant accomplishment made on propellants for unguided rockets since the end of the war" and "the first really practical and worthwhile replacement for JPN to come out of any development work."[70]

NOTS on the Eve of the Korean Conflict

This chapter merely hints at the array of projects under development at NOTS at mid-century. Rockets, fire-control systems, propellants, fuzes, and other products were making their way to the fleet with satisfactory frequency. During late 1949 and early 1950, however, a truncated budget, labor shortages, even a reduction-in-force necessitated abandoning some projects and refusing to begin others. As a 1949 article describing the station pointed out, "The full impact of its work has not yet been felt throughout the service; many of the naval weapons of the future are its research projects today."[71]

Despite budget and workforce limitations, the smart military-civilian team on the desert never stopped working on the weapons of the future, and when events on the Korean peninsula called for rapid production to meet the needs of war, NOTS was ready.

U.S. Navy photo NH 97059, courtesy Naval Historical Center

Navy and Marine Corps ordnancemen loading Holy Moses rockets and napalm on F4U-4B Corsair fighter-bombers on the deck of *Badoeng Strait* (CVE-116) during operations off Korea, December 1950.

7

Cold War Turned Hot

When the 1950–1953 conflict in Korea required new and improved weapons on a "crash" basis, the Naval Ordnance Test Station responded with new aerial rockets, launchers, and associated fire-control systems. Within days after U.S. involvement began, NOTS plunged into development of the 6.5-Inch Antitank Aircraft Rocket (ATAR) for use against heavily armored Communist tanks. China Lake conceived, built, tested, and shipped the first of these rockets to the battlefield in less than a month. Employees also worked at a furious pace on improved-performance versions of the 5.0-Inch High-Velocity Aircraft Rocket (Holy Moses) and other related rockets. Late in the conflict, Navy pilots began using the NOTS-developed 2.75-Inch FFAR, a small, reliable rocket that became a standard ground-attack weapon in Korea and in subsequent conflicts to this day.

A New Kind of War

Hostilities in Korea erupted at 4 a.m., 25 June 1950, with a barrage of North Korean artillery fire across the 38th parallel. In the days that followed, six well-equipped North Korean divisions marched southward through Seoul and beyond, accompanied by a hundred Soviet-made T-34 and T-70 tanks and supported by Soviet-provided aircraft. These events astonished the Western nations, but surprised the South Koreans only by their intensity. Guerrilla skirmishes initiated from the north had been going on for more than two years and had become more conspicuous since the U.S. had withdrawn in July 1949 from a four-year occupation of South Korea.

America's leaders were convinced by the sheer force of the North Korean drive that the Communists had issued a challenge that must be answered. The task would be difficult, since the United States was ill prepared for a major conventional war in terms of both moral climate and appropriate armament. The Truman administration had responded to the public's desire to hold the line on defense spending by focusing on nuclear retaliatory capacity at the expense of the resources needed for conventional warfare. Only two days before the conflict began, Secretary of Defense Louis A. Johnson was pushing the military services to cut another billion dollars from the next year's budget. On that fateful 25 June, the U.S. Navy's entire air presence in the vicinity of Korea consisted of two PBMs at Yokosuka, Japan. One carrier, *Valley Forge* (CV-45), with Carrier Air Group 5 on board, and one squadron of medium seaplanes were in the Philippines. The other services were similarly unprepared.[1]

Nevertheless, once the North Korean offensive began, the Truman administration worked rapidly and effectively to orchestrate U.S. actions and solicit a response from the United Nations. "The attack upon Korea makes it plain beyond all doubt that Communism has passed beyond the use of subversion to conquer independent nations and will now use armed invasion and war," the President said.[2] He ordered U.S. air and sea forces to support the South Korean resistance effort. During the two weeks following the 25 June attack, the U.N. Security Council called for North Korea to withdraw to the 38th parallel and recommended that the U.N. help the South Korean resistance under a unified command flying the U.N. flag. Sixteen nations eventually joined the combat in Korea, with the major burden of combat resting on American shoulders.

Thus the United States was once again at war—but in a strange new type of armed conflict in which no participating country officially declared war and in which both sides observed self-policed rules of limited warfare in the atomic age. For America and its U.N. allies, these limitations also included an understanding that the inviolability of existing borders would be observed.

In the early days of the Korean conflict, the Western allies shared the simple objective of restoring peace along the existing border, an arbitrary division of the country that had occurred along the 38th parallel at the end of World War II. Although the allies had intended the parallel to be a dividing line in name only, it had become much more significant with the establishment of separate North and South Korean governments, with the Soviets rigorously controlling passage across the parallel.[3] The U.S. later adopted the larger objective of unifying the two Koreas. The American fear was that allowing the Communists to succeed in Korea would mean subsequent Soviet expansion in other areas of the globe. The battle-weary NATO allies, particularly the British, feared a wider war and kept pressure on America to bring hostilities to a swift conclusion. But, as General of the Army Omar N. Bradley, chairman of the Joint Chiefs of Staff, had predicted from the start, the Korean conflict became a "long pull." In the end, neither side surrendered and both accepted a truce line that closely approximated the prewar status quo.[4]

Looking back on the course of the conflict, Lieutenant General James M. Gavin, one of the original members of the Weapons Systems Evaluation Group, observed that the U.S. "had neglected to develop and provide the technical means of winning anything but a total war, a total nuclear war. And Korea was not that kind of a war, nor were we willing to make it that kind of a war." Bradley made the point more succinctly: seeking total victory in Korea would commit American resources to "the wrong war, at the wrong place, at the wrong time, and with the wrong enemy."[5]

The reality of war in Korea reinforced the strategic view that had been outlined in the influential policy paper NSC 68. Many questions remained unanswered on specific programs and costs; nevertheless, President Truman approved NSC 68 as a statement of policy three months after war began in Korea. Thus the administration could legitimately claim that increases in defense spending were being guided by a long-range plan that had been drafted before the war. More to the point, the Korean conflict offered harsh validation of NSC 68's assumptions that the U.S. needed to build up its military might to counter Communist aggression.

The appropriations committees of both houses of Congress met in almost continuous session for the year following the conflict's outbreak, and an outpouring of more than $48 billion to the Defense Department in the form of supplemental appropriations was the result. This higher level of support continued, with Congress quadrupling the Navy's obligational authority from $4 billion to $16 billion between fiscal years 1950 and 1952. Although the main emphasis was on building up European defenses, the Truman administration interpreted the Korean experience as part of a broader Communist threat and strengthened the American military presence in the Philippines and Indochina.

Interestingly, although the additional funding that became available for NOTS and other defense R&D organizations supported a temporary expansion in development programs in rocketry and munitions for conventional warfare, in the longer term, the increased funding went mainly to strengthen the U.S. strategic nuclear striking forces.[6]

Quick Response From China Lake

Over the course of the Korean conflict, the station demonstrated the validity of its function as a complete RDT&E center by providing rapid, practical support as needed. The war's immediate effect on the Navy's desert lab was in a renewed demand for the air-launched rockets and associated fire-control systems that were China Lake's major products. Station employees worked at a furious pace on improved small- and medium-caliber rockets, including a folding-fin version of the 5.0-Inch HPAG Rocket. The pace accelerated at the Pasadena Annex too, where reliable torpedoes to attack submarines were urgently needed.

As new work and intensified demands on existing projects poured in, a sorely needed change in civilian employee hiring regulations gave the station new hope in recruitment. By mid-July, in response to an "immediate and urgent need for employment of personnel in connection with the Mutual Defense Assistance Program (Korea)," the Civil Service Commission authorized NOTS to make temporary job appointments "without regard to Civil Service registers."[7]

Professional recruits were desperately needed, since employees all over the station were working unreasonably long hours to meet the deadline for an antitank rocket scheduled to be shipped to Korea later that month. BuOrd authorized an additional 200 civilian employees in July, another 175 in September, and another 75 in October. By mid-1952, the station's civilian staff numbered more than 5,500.[8]

The recruitment program could easily be undermined if it coincided with a draft or callbacks to active reserve duty for those already working at NOTS. The reserve problem was not insignificant; about 100 of the station's most highly trained civilian employees were officers in the naval reserve and about 50 were reserve officers in other services.[9] Vieweg and the NOTS personnel staff worked hard to keep the talent at home where it could be used most effectively in support of the war effort. When Vieweg could make a case that a reservist possessed unique scientific and engineering talents, he could frequently gain a deferment. When an employee's skills were of a more general nature, however, the commander was often unsuccessful in his argument that the difficulty of recruiting, obtaining security clearances for, and training the personnel needed to support NOTS' important wartime work made it "essential that competent persons be retained, whether in civilian or military status."[10]

The competitive job market for critically needed occupations caused other frustrations. One tough job to fill was that of engineering draftsman. With defense mobilization causing a shortage of draftsmen everywhere, NOTS had to get in line behind industrial organizations that could promise more pay and more desirable living conditions. But China Lake's fabled can-do attitude was not confined to technical work. After someone in the Personnel Department suggested that NOTS could tap a reservoir of local talent to grow its own draftsmen, the station set up an intensive course of study for 22 local women, then assigned them to drafting boards. A June 1951 *Rocketeer* headline summed up the experience: "Housewife to Draftsman In Only Twelve Weeks."[11]

Engineering Department employees at work on technical drawings.

NOTS also relieved some of the work overload by contracting for data-assessment tasks. A trickle of work from China Lake to contractors in the Los Angeles Basin soon became a steady flow.

The establishment of contractors in Ridgecrest was the logical next step. Flying the raw data to Los Angeles and back caused about a day to be lost, with more time lost if corrections were needed. By moving the contractors to Ridgecrest, the data could be assessed and returned to the customer in an hour or less. New buildings appeared in Ridgecrest, and a small contractor community began to grow.[12]

The shortage of housing for new employees continued to be a major recruitment roadblock. Until recruits and housing could be provided in sufficient numbers, the station's existing work force accepted the challenge to work long hours. Vieweg at first resisted the option of mandating a longer workweek, since many employees were already voluntarily working around the clock. After the President proclaimed a national emergency in December 1950, however, the station briefly instituted a six-day, 48-hour workweek.[13] Thompson later admitted that a prime objective of the six-day week was to give "proper publicity" to the extra effort that was already being made.[14]

Holy Moses—the Bird in Hand

The first rocket used in Korea was the 5.0-Inch HVAR, Holy Moses, a Caltech- and NOTS-developed rocket that had proved itself in battle during World War II. When the first air strike of the Korean conflict began, just after dawn on 3 July 1950, *Valley Forge* catapulted 16 F4U Corsairs, a dozen bomb-laden AD Skyraiders, and eight F9F-2 Panthers into the skies over the Yellow Sea. Eight HVARs rode on their individual launchers under the wings of each Corsair. The target was the airfield at Pyongyang, capitol of North Korea. The bomb and rocket damage sustained in this strike (two North Korean aircraft destroyed in the air and nine on the ground) was no doubt less significant than the psychological impact the Panthers, the first jet fighters used by the U.S. Navy in combat, had on the other side.[15]

Holy Moses was a literal "smash hit" in another early strike on North Korea. Panthers from Air Group 5 of *Valley Forge* flying a reconnaissance arc over North Korea's craggy northeast coast spotted an oil refinery on the curving south shore of Wonsan's harbor. The Wonsan Oil Refining Factory was an important target because it produced about 500 tons of refined petroleum products daily for its Korean and Russian proprietors. On 18 July 1950, "Happy Valley" launched 10 Corsairs, each carrying eight HVARs and 20mm ammunition; and 11 Skyraiders, each carrying two HVARs, a 1,000-pound bomb, and a 500-pound bomb.

After the Corsairs rocketed the storage and cracking facilities, the Skyraiders completed the destruction with a pattern of bombs. The demolished refinery took four days to burn itself out in a black column of smoke visible (and useful as a navigation aid) from 60 miles away.[16]

As the long summer wore on into fall, North Korean pressure on Pusan was unrelenting. Determined ground troops, supported by naval firepower, held fast. That September the rockets that had first been air-fired at NOTS again proved their worth when General of the Army Douglas MacArthur established a second front in an amphibious assault on Inchon, a swampy port on the Yellow Sea 18 miles west of Seoul and only 35 miles south of the 38th parallel. The success of the Inchon assault depended on conquering a series of offshore islands, in particular Wolmi-do, an unimpressive lump of land rising 350 feet above the surrounding mudflats. The JCS had been resistant to MacArthur's Inchon venture, but so confident was he of success that on 13 September a flagship full of dignitaries and members of the press arrived offshore to enjoy the show. Among this throng was Dr. Charles Lauritsen.

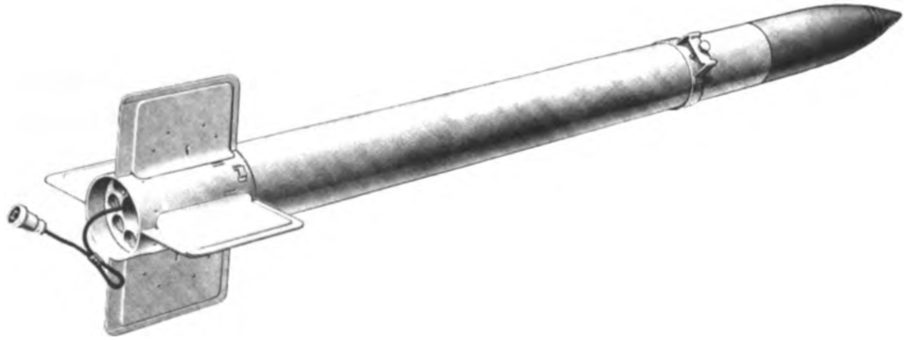
As Corsairs rocketed the harbor with HVARs, Lauritsen was proud to witness results from the Caltech rockets that had been developed and tested at the Navy lab he had been instrumental in establishing. In his words, the HVARs "plastered Inchon and especially the little island in the harbor there, Wolmi-do, they just practically wiped it out." He was also thrilled to learn two days later that U.S. Marines had landed on Inchon, aided significantly by three specially configured U.S. rocket ships (LSMRs), each firing a thousand of Caltech's powerful 5.0-Inch spin-stabilized barrage rockets.[17]

But the honeymoon period for Caltech's World War II-era rockets soon ended. Navy and Marine Corps pilots discovered problems with the HVAR that made it less than satisfactory for its intended air-to-ground use. For one thing, the rocket was too slow. To withstand the heat of its external-burning propellant grain, the HVAR was sheathed in cumbersome steel nearly a quarter of an inch thick. According to Pat Patton, the steel made the rocket "heavy as hell, and then you wasted a lot of energy accelerating that steel."[18] In addition, the rocket's behavior became erratic in cold weather. Pilots disliked using HVAR for night attack because the flash from the rockets could cause temporary blindness. Furthermore, since each launcher could hold only one of the fixed-fin HVARs, a plane could generally carry only six rockets.[19]

To add to these shortcomings, pilots discovered that a long wire (or pigtail) connecting one of the rocket's nozzles to the launcher's ignition circuit was too fragile to withstand for long the wear and tear of the carrier environment.

U.S. Navy photo 8D-G-439903, National Archives

Rocket strike against Wonsan oil refinery, 18 July 1950.



The 5.0-Inch High-Velocity Aircraft Rocket "Holy Moses."

Pigtails could break loose and whip around in the airstream, causing misfires and aircraft skin damage. The host aircraft could also be damaged by igniter wires and nozzle seals ejected as the rocket fired.[20]

Insufficient training added to HVAR's woes. "It was evident from observations of the squadron armament lines that immediate training was absolutely essential since almost all types of dangerous and damaging practices were being committed," reported Stanley J. "Stan" Marcus, the first NOTS engineer to visit the front. "Two fatal accidents had already occurred and the pilots were complaining of a very large percentage of rockets which had erratic trajectories."[21]

More than a year later, when Patton took a turn as a technical observer in Korea, the pilots were still unhappy with HVAR performance, and poor training was still a major part of the problem. Patton was puzzled about complaints that the rockets "went all over the sky." After observing an ordnance technician assembling the rockets, he had his answer:

> [T]he ordnance guy would take the fins and bend them down so he could tighten the screws with a speed wrench and then bend them back up again. I said to the ordnance officer, "It's not hard to understand why you're having dispersion problems. Treat the rounds like that! After all, that's what the fins are on there for, to make it go straight."[22]

Despite these shortcomings, though, until China Lake rocket scientists could field more promising rockets, Holy Moses would be the "bird in the hand." So extensively was HVAR used in Korea that the massive stockpiles of rounds left over from World War II were rapidly expended, and the bureau began new production.[23] In the meantime, NOTS worked overtime to come up with alternatives.

Tank-Buster Needed

When word came from the front in July 1950 that rockets were urgently needed to penetrate North Korea's heavily armored Russian-built tanks, the entire station pitched in to meet the need. In an amazingly short time—less than a month—the 6.5-Inch Antitank Aircraft Rocket (ATAR) was designed, constructed, and tested at NOTS; the first 600 rockets were hand-built at China Lake and Pasadena; and the first planeload of rockets was on its way to Korea. Somewhere along the way, BuOrd officials gave the rocket an appropriate nickname—Ram. For folks at NOTS, the tank-buster was "the shaped charge" in reference to the rocket's shaped-charge warhead, which could project a powerful jet of molten metal to punch a hole through the stoutest armor plate a tank could conceivably carry.

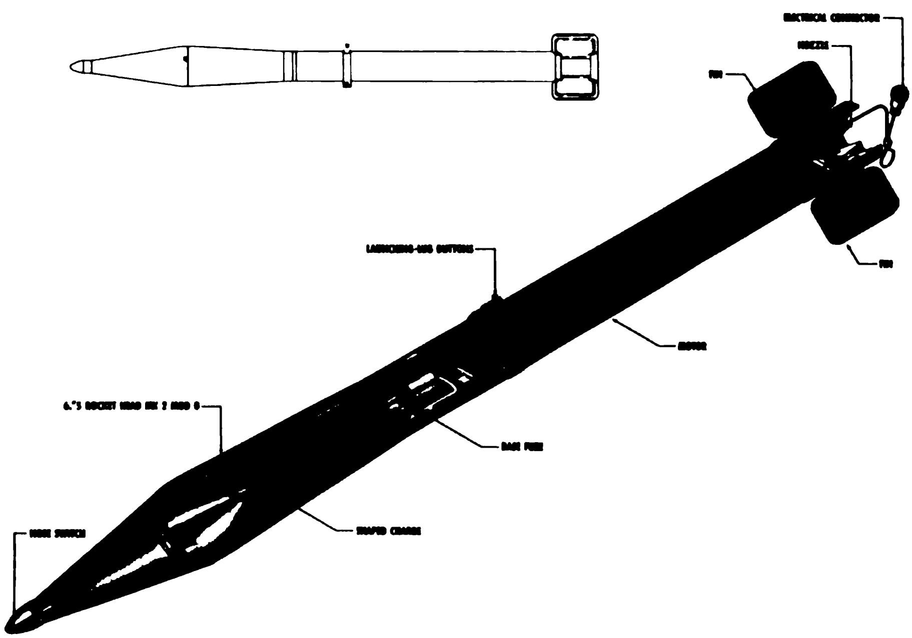
Here was a project that could be accomplished only in a place that possessed all the resources and talents necessary to carry the project through from idea to reality. Given the opportunity to show the world what technical competence could accomplish, China Lake and Pasadena employees from every department worked long, productive days to complete the task.

Although the crucial month for Ram was July 1950, the station's involvement with shaped charges had started back in 1947, with a short-lived, low-priority program to develop an 11.75-inch-diameter shaped-charge warhead for China Lake's World War II bunker-buster, Tiny Tim.[24] In 1949 Explosives Department employee Ted Parker performed a new series of experiments that confirmed that a powerful antitank rocket could be made from a shaped-charge head affixed to one of the NOTS family of rockets. In late 1949 the Research Board recommended continuing work on shaped charges. Thompson subsequently sold BuOrd authorities on the concept. But the tight defense budget of the era meant that money was not available for the development of a good idea for which no critical need existed.[25]

That need arrived only days after the Korean war erupted when Secretary of Defense Johnson received information from the front that massive JS-3 (Joseph Stalin) tanks were en route from Russia to North Korea on the Trans-Siberian Railway. This news was worrisome, since bazooka shells and aerial rockets were reportedly unable to pierce the JS-3's thick steel shell. Bazooka shells themselves employed shaped charges and had been used as antitank weapons during World War II, but new, more rapid fuzing was required to adapt shaped charges for use in high-velocity aircraft rockets.[26] On 4 July 1950, Johnson asked the Research and Development Board if the defense establishment had a shell that would work against the North Korean tanks. Getting the answer that such a shell existed, but "only on the drawing board," Johnson demanded that this new weapon be produced and shipped to Korea by 4 August.[27]

NOTS owned that drawing board, and BuOrd wasted no time in passing along the urgent task. On 6 July China Lake was officially assigned the project. Thompson immediately established a task group, giving Commander Levering Smith, acting head of the Rockets and Explosives Department, overall responsibility. Smith delegated project supervision to Ellis, head of Rocket Ordnance, who in turn enlisted Patton, head of the Ordnance Branch. Patton needed to keep his own efforts focused on development of the 2.75-Inch FFAR and other high-priority tasks, so he assigned day-to-day management of the new rocket to Stan Marcus, his "red-hot, get-it-done guy."[28] To Rod McClung was given the task of developing a specialized fuze for the rocket. As head of the Special Devices Branch, McClung ordinarily supervised the work of others, but for this "crash" project he took on the fuze design himself.

The group decided to use the 5.0-Inch HVAR for the rocket body. The idea of mounting a new shaped-charge head on this battle-proven rocket made sense: tests of the rocket itself could be curtailed, since important parts of the system had already been proven effective. Guy Throner, head of the Test Department's Ordnance Service Branch, had responsibility for warhead



NOTS 872, Rocket Department Technical Appraisal

The 6.5-Inch Antitank Antiaircraft Rocket Ram or "the shaped charge."

development. The self-assured Throner was so expert with explosives, the story went, that he could write your name—or preferably his own—on a sheet of steel with explosives.[29] His expertise would be invaluable for the work on the new warhead.

The word from the bureau was that the armor plate to be penetrated was 18 inches thick. Conjuring up a mental picture of the stout tank necessary to carry armor plate of that thickness, the task group gulped, factored in an angle of obliquity to account for the angle at which the rocket would strike the tank and for the slope of the armor, and concluded that the new rocket's warhead would have to be capable of punching a hole through 24 inches of armor plate. Throner ventured the opinion that a shaped charge of at least 6 inches in diameter would be needed to penetrate armor that thick. "Well, go do it," Thompson told him.[30]

Work on ATAR involved virtually the entire station, cutting across all department lines and going on around the clock for seven days a week. Ellis set the example, asking no more of the rest of the team than he asked of himself. "I remember that we all got together and convinced Dr. Ellis that it was the decent thing to do to take at least a day off when his mother died, so he agreed to go home and grieve for his mother, except that he was back on the job 4 hours later," recalled McClung.[31] Thompson himself was also on hand at all hours. "I went through the shops here at night and talked to the people in the various parts of the laboratory, and there was a spark there that is just precious beyond any measure," he later told senior employees.[32]

A critical part of the project was the fuze, which would have to function at the precise moment needed, since the effectiveness of the shaped charge would depend on detonation of the warhead at the proper standoff distance. McClung started with a simple electric contact fuze, then modified it with a capacitor charged by a battery and wired to an igniter in the base of the warhead. He and his helpers got the job done in a hurry by buying out Ridgecrest's entire stock of spring clothespins and hearing-aid batteries and adapting these mundane items to the task. The makeshift device worked well but lacked the safety features a fuze would ordinarily have. McClung called this fuze "probably the most dangerous piece of ordnance that was ever sent to the field," but added that "The Rams weren't as dangerous as the Russian tanks, so we were willing to take the risk with them, and, as far as I know, none of the Rams ever blew an airplane out of the sky."

Once the fuze was designed, it needed to be manufactured. Employees with other jobs during the day became willing workers on a nighttime fuze assembly line that stretched down the 762-foot length of Michelson Lab's main corridor and snaked around into one of the side corridors. Engineers, administrators, and secretaries—anyone who could hold a soldering gun—pitched in to get the job done. McClung remembered that Dr. John H. Shenk, head of the Research Department, worked so intensely at the fuze-assembly task that he "wound up with blisters on blisters."[33] At the end of each long evening's work a pallet-load of completed fuzes was ready for delivery to CLPP for assembly of fuzes and warheads into the rockets. The last job each night was to tear the production line down so that the corridors were free for daytime use. The next evening gray metal conference tables would again line the hall, ready for that night's work.[34]


Courtesy Maturango Museum

Roderick M. "Rod" McClung at an Aviation Ordnance Department Christmas party.

In the meantime, Ballistics Division employees were making rapid calculations to determine whether rigging a shaped-charge head on an HVAR body would result in a rocket that would fly and hit its target. Leroy Riggs, a fresh-faced ballistician then barely into his second year of work at NOTS, was assigned the task of coordinating the fabrication and test of dummy warheads. At Riggs' request the Public Works Carpentry Shop fabricated a batch of hollow wooden cones, each 6.5 inches in diameter. As each cone came off the turning lathe, it was bolted to the outside of a standard steel HVAR head that was loaded with lead to accommodate for the change in the center of gravity.[35]

As soon as the dummy rockets were ready, Lieutenant (j.g.) Newton L. Wheat took them up over B Range on his F4U-4 Corsair for the first dozen test flights. Each flight involved firing a pair of rockets simultaneously, one from each wing of the aircraft, with a given dive angle, airspeed, and slant range.[36] Cameras mounted on the aircraft and Askania cinetheodolites documented these firings, thus allowing the ballisticians to calculate flight tables. These tables, which gave information on the lead angles for every range and speed, were an essential part of the development task because the pilots destined to use the rocket would have no fire-control equipment, but would have to depend on simple gun-barrel sights. The tables were not easy to come up with in those days. The tools at hand were a few mechanical Friden and Monroe calculators, plus some old Marchant calculators with clunky hand-operated levers reminiscent of slot machines. Riggs remembered working on the calculations every day until 3 or 4 a.m. After a hurried breakfast and a short nap, he and the other ballisticians would be back at work the next morning.[37]

The team working on the shaped-charge warhead wasn't getting much sleep, either. To demonstrate initial warhead feasibility, Throner used cones left over from Ted Parker's experiments, casting Composition B explosive behind the cones. So hurried were preparations for the first test that Ellis helped Throner load charges on his desk at Salt Wells. "We violated a few rules, but were reasonably careful," Ellis recalled. "Even wore safety glasses."[38]

Steel plate simulating the JS-3 tank was needed to test the shaped-charge warhead. Once again the resourceful NOTS team was able to find a locally available source. Part of the station's World War II legacy was a war-surplus treasure-trove that Warner had accumulated and shipped to the desert for future use. "Fortunately, in the surplus material Art Warner had collected were pieces of 12-inch armor plate, so, putting two plates together, we were able to test the shaped-charge head statically over on the east side of the range, and sure enough, it penetrated all 24 inches," said Levering Smith.[39]

U.S. Navy photo NP/45 37965 courtesy Maturango Museum

China Lake warhead test at night, 1952.

The camera sees exploding fragments as streaks of light; hot gas illuminates the center of the photograph.


U.S. Navy photo, courtesy Felice Plain Mueller

Haskell G. "Hack" Wilson.

One of the workers swept up in the whirlpool of warhead testing activity at the 1,500-foot launcher rails of the K-2 Terminal Ballistics Range was Hack Wilson, a new employee Throner had recruited from Re2b. Hack and Jane Wilson had been en route to China Lake when the Korean conflict began, and their arrival on the desert coincided with the most harried phase of the ATAR work.

Instead of the desk job in Central Staff that he expected, Wilson began working on ATAR tests from the moment he set down his suitcases. The darkness of night provided the best photographic backdrop for studying the jet effect of the shaped charge, and daylight hours were occupied with hasty preparations for the next night's test. As Wilson remembered, "Every night was test night, and after the tests were run that night, everybody knew what we had to do before the next night."[40] The normally imperturbable Jane Wilson admitted to a few worries when her husband simply disappeared, leaving her and two young daughters alone in a strange community.[41]

To obtain the best possible shaped-charge performance, the NOTS team decided to use an explosive lens to control the initiation of the main charge. Modifying a lens was no problem for the experienced workers at Salt Wells, who could apply expertise they acquired in wartime work on explosive components for the first atom bombs. By 1950, as Levering Smith commented dryly, "we knew quite well how to design that lens." The team used 6-inch steel pipe for the charge case. Although the pipe was somewhat heavier than needed, it had the telling advantage of being available. A similar practical concern motivated selection of the metal for the charge. "We didn't have copper to make the conventional cone, so we decided to try steel," Smith recalled.[42]

As soon as the first hurried tests showed that the warhead's design would work, employees at the China Lake and Foothill Plant machine shops swiftly fabricated steel warhead shapes, which were then delivered to CLPP by truck. The all-volunteer team of ordnancemen putting the shaped-charge components together at CLPP had been cautioned to handle the components with care. "It was dangerous work," McClung said, adding,

> After the rounds had all been assembled and shipped, we took everybody at the pilot plant on a bus to K Range, where we fired one of the Rams against a big sheet of armor. On the way back, many of the men on the bus confessed that if we'd had the firing before the assembly work, it wouldn't have gotten done.[43]

The first prototypes rolling off the pilot plant's assembly line were used in hurried aerial tests against the stout concrete walls at Charlie Range. The instant the tests showed feasibility, Riggs decided, "Those are good lead angles. Go shoot them."[44]

As follow-on tests continued, the first 200 handcrafted ATAR heads, Model 101A, were rapidly loaded on Air Force cargo planes, which left NOTS on 29 July—just 19 days after formation of the ATAR project team. In another remarkable accomplishment, a formal report containing technical descriptions and firing tables of the new weapon accompanied each ATAR head.[45] Along with the precious cargo went Stan Marcus. When the persistent Marcus wanted something, he generally got it, and this time he wanted to see the first use in combat of the rocket on which he had worked so intensely.

U.S. Navy photo NP/45 30101, courtesy Maturango Museum, Erma Peirson estate

Ram rockets on F4U Corsair ready for takeoff from Armitage Field for test over China Lake ranges, 17 July 1950.

Troubleshooting in Korea

When the ATAR-laden cargo aircraft lumbered up out of China Lake that 29 July, Marcus was in the hold of one of the planes, perched atop the rocket crates. A 24-hour delay in Alaska allowed the precious ATAR warheads to be redistributed for security's sake. On the next leg of the trip Marcus rode somewhat more comfortably with half the heads on a commercial cargo plane, while Major Joseph S. Restifo, USAF, accompanied the other half on a separate route on an Air Force plane. At their destination Marcus and Restifo began introducing the new weapon to the Far East Air Forces.

Marcus first briefed representatives of the 8th Fighter-Bomber Wing, 5th Air Force, at Itazuke Air Base in Japan, then flew on to Korea to visit the 39th and 40th Fighter Squadrons at Pohang. When the action at Pohang heated up, he was evacuated to Tsuki and Sasebo, Japan. At every stop he preached the advantages of the new antitank weapon. To his surprise, he encountered mixed reactions. At Itazuke he discovered that F-80 pilots resisted using their limited weapons stowage space for rockets seen as useful only against tanks. The F-51 fighter pilots based at Pohang were more receptive, however, since their slower propeller-driven aircraft were located close to the actual combat operations and thus could afford to carry more weapons and less fuel than could the F-80s.

"Since the United Nations forces were definitely on the defensive, collection of even the primary kill data was very difficult, not to mention detailed information on the individual firings," Marcus reported glumly. His attempts to use gun cameras to record the range and dive angle of the firings were frustrated because no film was available. "The only worthwhile information to be secured was obtained through individual interrogations of the pilots, and since the squadron bases were shifted at several times and the rounds were being carried from at least two bases, even these data were difficult to obtain," he said. Nevertheless, he was able to report the first successful use of Ram in battle:

> After compiling all the information possible under the adverse combat conditions, it appeared that about four enemy tanks were killed by the use of about 80 rounds fired from F-51 aircraft based at Pohang and Itazuke Air Base. The best data emanating from Taegu and Ashiya Air Base using about 70 rockets under the cognizance of Major Restifo, indicated that about four or five more sure kills were credited. Thus, it appears that at least eight tanks were credited to about 150 rounds.

Combat pilots reported that they could not see the initial explosion at impact, but that after a short delay the target tank would explode, with little flame but voluminous black smoke. Marcus speculated that fuel and ammunition fires inside the tank were responsible for these invariable secondary explosions. The rocket functioned as designed—when it scored a hit.

China Lakers welcomed the news. Marcus also passed along disconcerting information obtained in his meeting with the commanding officer of the 8th Fighter-Bomber Wing. Earlier reported ricochets of 5.0-Inch HVARs fired at tanks "were probably considerably fewer than reported and possibly even non-existent." Furthermore, "Very few, if any, JS-3 (57 ton) tanks have been observed in Korea." Not only was it likely that the presence of heavily armored Joseph Stalin tanks was apocryphal, but it also appeared that rockets already in use might be able to do the job against the existing tank threat.

Clearly one of the lessons to be learned from the Ram experience was the importance of direct communication between a weapon's developers and its users. Furthermore, the usefulness of sending technical advisors out among the operating forces rapidly became evident, not just because Marcus was there to advise on Ram's use, but primarily because he found "all types of dangerous and damaging practices" in squadron armament lines handling the 5.0-Inch HVAR. He had started out with one goal in mind—the introduction of Ram—but he soon discovered that his first job must be to give the operating forces whatever technical assistance they needed to meet the exigencies of war. Consequently, during the month he and Restifo were in Korea, they spent much of their time helping the Air Force train armament personnel in HVAR assembly and loading procedures.[46]

Similar experiences awaited Throner and Lieutenant Commander Richard Brown, Commander Fighter Air, Alameda, who arrived in Japan mere days after Marcus and Restifo. If the first shipment of ATAR heads had taken a rather roundabout route to reach Korea, this second load had an even more tortuous journey. The rocket heads were sent first by cargo plane to Moffett Field and reloaded onto two aircraft traveling to Barber's Point, then onto one aircraft for delivery to the Air Force base at Itazuke. The next leg of the journey, a truck ride to Fleet Activities, Sasebo, was the most harrowing part of the trip. Throner's and Brown's trip report commented wryly that "it is safe to say that if a rocket can survive the truck trip to Sasebo, there should be very little worry concerning its ability to stand rough handling in shipping boxes."[47]

This second team spent about a month instructing Navy pilots on two large aircraft carriers, *Valley Forge* and *Philippine Sea* (CV-47), as well as on two smaller "jeep carriers," *Badoeng Strait* and *Sicily* (CVE-118), all based at Sasebo. At the same time Major Claude H. Welch, Marine Service Squadron

12, concentrated on a parallel ATAR introduction effort for Marine Corps pilots on board *Sicily*.[48]

During these early months of the war, as the North Koreans pushed the allied forces south toward Pusan, the Air Force was forced to withdraw its tactical aircraft from Korea and reposition them in Japan. Consequently, the fuel-gulping Air Force jets had to sacrifice weapons for more fuel, and the Navy and Marine squadrons' ability to deliver ordnance from carriers floating just off the Korean coast became critically important. When the NOTS visitors arrived, the carriers were in the thick of the action. Operating with squadrons of tough, old F4U Corsair fighter-bombers and newer AD Skyraider attack aircraft (both of which were able to carry heavy loads of ordnance), the carriers became mobile airfields replacing those on the ground that had been overrun by the North Korean army.[49]

Although Throner and Brown initially hoped to concentrate on convincing Navy and Marine pilots to add Ram to the loads of armament with which their aircraft lumbered off the carrier decks, the two China Lakers soon realized, just as Marcus and Restifo had, that their mission would have to be expanded to deal with more pressing problems. Every officer and enlisted man Throner and Brown encountered hungered for more training on the entire arsenal. Throner created a table designed to help the carrier pilots select bombs and fuzes appropriate to their targets.[50] Both men worked overtime to share their rocket, bomb, and fuze knowledge with fleet personnel.

Brown and Throner reported that Ram functioned well, but that additional ballistic studies and more adequate sighting data could improve its performance. Echoing Marcus' experience, this second team reported resistance to the new weapon. The pilots didn't realize that the shaped-charge warhead could be used against several other types of ground targets. "As presently used, the ATAR is only loaded upon planes as a result of a direct call for anti-tank ordnance," Throner and Brown reported. "Unfortunately, there is rarely time to send a special plane with a special load against a tank." Welch picked up similar information from *Sicily*'s Corsair squadron VMF-214, the famed "Black Sheep" of World War II and the first Marine squadron in Korea.[51]

Just as Marcus had, Throner and Brown reported numerous instances of HVAR malfunctions. The carrier environment provided practical reinforcement for the concept that weapons must be as simple and rugged as possible. Weapons of choice, Throner and Brown observed, were 20mm guns and 100-pound bombs. The guns were wearing out from overuse and being kept in operating condition only by cannibalizing parts from damaged guns. As for the bombs,

NOTS-developed ordnance in use during operations off the Korean coast, May 1951. Ordnancemen on the deck of *Philippine Sea* load Ram rockets beneath the wing of a Fighter Squadron 64 F4U-4B Corsair. Two Holy Moses rockets are mounted just above the Rams. China Lake also developed the rocket carts and launchers shown here.

pilots "feel that all the bomb's explosive power is useful instead of part of its weight being rocket motor; that it is easier to handle and load aboard ship, and that more bombs than rockets can be carried in the same magazine stowage space." Here were lessons the station could—and did—apply to its subsequent rocket designs, where smaller size and disposable launchers would be stressed.

After he left the carriers, Throner stopped off in Tokyo to brief Vice Admiral C. Turner Joy, Commander Naval Forces, Far East, and his staff. Throner was able to describe three reported ATAR hits, all causing substantial damage to their tank targets.[52] His conversation with the admiral was representative of several discussions where NOTS visitors to Korea tried to persuade military leaders that the new rocket could be used against many types of targets, not just tanks. However, the word "antitank" in ATAR's name (not to mention the manual, which described only antitank use) seemed to work against acceptance of a more versatile application.[53] When Patton revisited Korea in early 1952, he was disconcerted to find Ram rockets stacked at the ordnance dump, their cases (standard Navy shell cases) taken home by Koreans, who adapted them for cooking pots. Patton again urged more widespread use of ATAR.[54]

Ram's mixed reception in Korea was not reflected in the press, where the new rocket was reported as devastatingly effective. An F4U Corsair carrying eight Rams had "a firepower greater than the broadside of a big, 2,200-ton destroyer firing all 5-in. guns," according to the Associated Press.[55]

The station also received welcome recognition through official channels. Speculating that Ram's "timely availability to our fighting forces may contribute substantially to an early victory," Secretary of the Navy Francis P. Matthews acknowledged that "the uniqueness of the existence at one geographical location of the complete organization and facilities to support such a development" was an important factor in this accomplishment. He also praised "the spontaneous enthusiasm and aggressive determination of the personnel of the Naval Ordnance Test Station and their willingness to work unusually extended periods of time when necessary for the early accomplishment of this project at a critical stage in the Korean situation."[56]

An exact determination of the number of days—variously cited as 19, 23, 24, 28, or less than 30—that the station took to build and ship the first rockets would depend on the date selected as the official beginning of the project. In any case, the work was accomplished at a blazing speed and through a remarkable demonstration of teamwork. "The contributions of the groups responsible for this achievement have demonstrated the effectiveness, resourcefulness and flexibility of the organization and have confirmed in an effective manner the advantages of having in one place the complete facilities of a development center," Thompson said. "It is apparent that every part of the organization, extending all of the way from the Research Department through the test facilities and service departments has been involved, and was necessary in accomplishing the result."[57]

With the urgent need for a tank-buster met, the NOTS team had time to investigate a nagging question that lurked behind the development specifications. Bill McLean, for one, found it difficult to believe the Russian tanks had enough power to move around on rough terrain carrying the thick armor that had been reported to NOTS. "Upon investigation," he said, "we found that the actual armor of the tanks had a thickness of somewhere between 3 and 4 inches, and that the specification given us had resulted from the correction for obliquity having been made twice before, while the specification was coming through channels." As a result, NOTS had designed Ram to pack a much more powerful punch than was actually needed. "It is this type of well-meant distortion that makes it essential for the designer to question his specifications and to go back to primary sources in order to develop a real understanding of his problem and the basis for the need, if he is to create a successful product," McLean noted.[58]

More exact information about the nature of the target might have resulted in additional economies of size and weight, but it is doubtful that these differences in themselves would have improved the rocket's reception in Korea. Although ATAR worked considerably better than HVAR against tanks and armored targets, the new rocket's drawbacks did not endear it to pilots. To deliver the rocket accurately, the pilot had to swoop low over his intended target, which, as Hack Wilson said, "really meant that that tank had to be in an undefended area."[59]

From the pilot's perspective, if he had to risk bringing his plane in that low, he had a more effective weapon in the gelatinous gasoline product, napalm. A 150-gallon napalm bomb dropped from as low as 200 feet generated a fireball that incinerated everything within a 100-by-275-foot area, thus requiring far less accuracy than that called for by ATAR or HVAR.[60]

Within the next few months about 5,000 additional ATAR rounds, procured mainly from industrial sources, were shipped to Korea, and a more carefully engineered version was developed for mass production by industry.[61] In 1950–1951 the Thermador Electrical Manufacturing Company in Los Angeles produced 65,000 additional Ram warheads under contract to BuOrd. These Mk 2 Mod 0 prototype heads were lighter in weight (and thus closer in weight to HVAR) than were the original Mk 1 Mod 0 heads. A safer fuze was also incorporated. In late 1951 Thermador started work on 80,000 additional heads, but this new contract was never completed.

Ram was removed from service in 1953, having been used only during the Korean conflict and even there with relatively inconsequential results. As Thompson suggested, however, the development of Ram was militarily significant in that the rocket showed that aircraft-projected weapons could defeat the heaviest mechanized land armor. "This demonstration by the combined air arms of the United States military establishment may be more important, in the end, than the destruction of a certain number of tanks in Korea," he wrote.[62]

A New Rocket for a New Type of Warfare

Once ATAR went to war, China Lakers worked scarcely less obsessively on other rocket projects, in particular a small, reliable rocket destined to become a standard ground-attack weapon in Korea and in subsequent battles to this day. The 2.75-Inch FFAR, Mighty Mouse, had been designed for "shotgun" salvo firings from interceptor aircraft against hostile bombers. But Navy pilots reported that large-scale air strikes, effective in World War II, were seldom appropriate in Korea. Instead, carrier pilots were flying more than half their offensive sorties in armed reconnaissance to disrupt enemy supply lines. The two to four aircraft in a usual sortie would seek out and destroy targets along 20 to 70 miles of highways and railroads. When several innocuous-looking North Korean ox carts vaporized as hidden loads of ammunition exploded under allied fire, pilots stopped complaining that carts were undignified targets.[63]

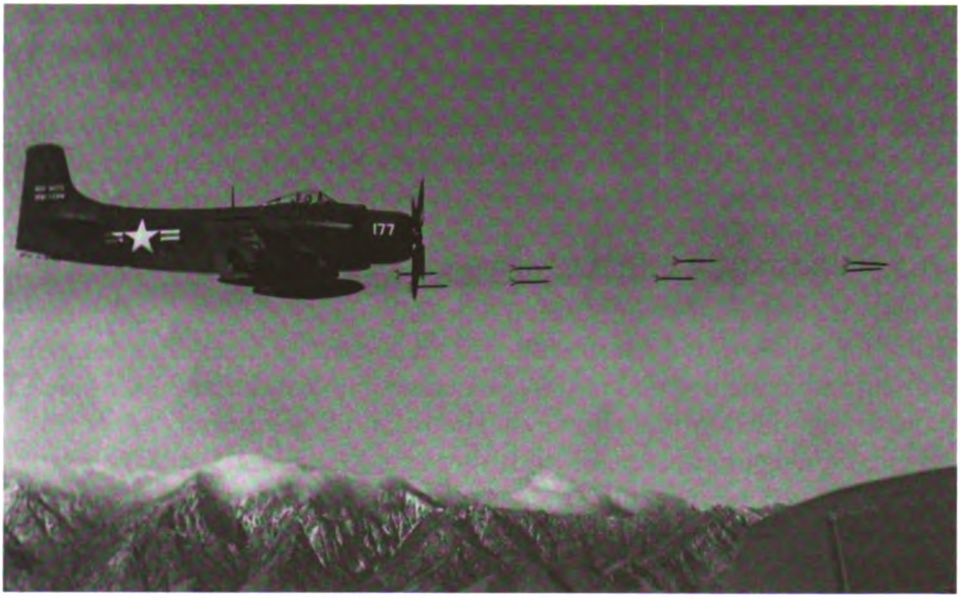
In January 1951 carrier-based Task Force 77 off Korea's east coast began working to cut off the northeastern supply network of rail lines and roads as part of a concerted Navy, Air Force, and Marine interdiction effort.[64] In the 20-month campaign against enemy supply lines, more than 13,000 breaks were made in rail tracks, and 500 bridges and 300 bridge bypasses were destroyed in northeastern Korea. As rapidly as the pilots bombed and rocketed tunnels, bridges, roads, and rail tracks, however, the Communists methodically filled in, rebuilt, or simply walked around the damage.[65] The interdiction efforts, as wide-ranging and destructive as they were, could do little more than slow the movement of enemy supplies through Korea's steep, twisted valleys. "Operation Strangle," a June–September 1951 effort assigning TF 77 to destroy every target within a strip of latitude a single degree wide, was a more concentrated effort—and also unsuccessful.

TF 77, which had added interdiction efforts to its continuing close-air support of front-line troops, received orders in September to focus its resources exclusively on interdiction. Carrier pilots made more than a thousand individual road and rail breaks in the month of October alone—an impressive accomplishment, considering that each narrow set of tracks could be destroyed only with a direct hit. The track-busting effort continued vigorously into early 1952, when the carrier pilots began "night heckling" operations designed to take advantage of the visibility offered by the moonbrightened, snowy winter nights. Weapons of choice were napalm and bombs, with HVARs an infrequently used option.

For the immediate problem facing fleet pilots, Mighty Mouse was a promising alternative to HVAR. Salvos of FFARs fired from disposable pods could be used much like shotguns to blast a broad area with shrapnel, thus going a long way toward solving the night-accuracy problem.[66] One of the new rocket's most avid fans was the station's politically astute experimental officer, Captain (later Admiral) Thomas H. Moorer, who began a campaign in OPNAV to speed fleet introduction of FFAR in Korea. Moorer's intimate knowledge of the rocket, gained through daily interaction with its developers, helped him convince the Air Warfare Division (OP-55) that a fuze modification to provide instantaneous rather than delayed action would make FFAR a superior weapon against ground targets. In December 1951 OP-55 gave the go-ahead for land-based Marines to evaluate air-to-ground use in early 1952.[67]

Station rocketeers then completed a rapid fuze modification for FFAR's air-to-ground application. But they realized that the operational environment might well demonstrate the need for further modifications, so they decided to send a technical expert with the first shipment to Korea. As head of the Rocket Department's Projects Division, Pat Patton picked himself to go. "I wasn't about to assign it to anybody else," he said. In mid-February 1952 Patton accompanied several crates of the rockets to Korea. The initial tests of the new rockets and their launchers would be by a squadron of the First Marine Aircraft Wing, flying Douglas AD-4 Skyraiders, hefty propeller-driven aircraft nicknamed the "Blue Airplanes" by the North Koreans.[68] The tests would involve six-round aluminum launchers developed by NOTS and manufactured by Douglas Aircraft Company.

Patton discovered, as had his predecessors, that much of his time was needed for temporary fixes for unexpected problems. He was foiled at first in



U.S. Navy photo NP/45 26970, courtesy Maturango Museum, Erma Peirson collection

AD Skyraider aircraft firing Mighty Mouse salvo over China Lake ranges, 26 January 1950.

his efforts to collect important documentation on rocket impact. An ingenious gun camera mounted on an attacking aircraft was designed to photograph the rockets at impact. As the Skyraider accelerated into its pullout, an unbalanced weight on the camera was supposed to rotate a prism so that the camera would keep its line of sight on the rockets. Unfortunately, as Patton remembered:

> [A]s soon as they started the least bit of pull-up, this prism went clear to the extreme end. It was obviously undersprung, undercompensated; and when we fired against a target, which was an area near Pohang in the sand dunes, immediately the gun camera records went "choop" like that, and we got a tantalizing one- or two-frame look as the line of sight zipped past.

Patton began makeshift efforts to compensate for the limitations of the tools at hand. He drew ruled lines on letter paper to make his own graph paper, used his own spinning body as an improvised centrifuge to calibrate the camera, and worked late into the night making hand calculations for the calibration. Through these expedients and help from the Marines, he was able to obtain a few precious impact pictures to take back to China Lake.[69]

Paul Shea, a mechanical engineer in the AOD Aircraft Projects Branch, soon arrived, bringing along several innovative NOTS-developed launching pods—seven-round packages formed by cardboard mailing tubes coated with plastic. Early firing tests had proved that simply shielding each tube's leading edge with a thin metal cap added strength enough that the tube could withstand the forces of an FFAR launching. To make the pod more streamlined, the outside flutes between the tubes were filled with wooden sticks and the entire bundle was covered with glass cloth. These pods were part of a prototype lot of 230 aircraft rocket launchers (Mk 16 Mod 0) manufactured under contract to NOTS by Century Engineers Inc. for simultaneous evaluation by China Lake and four other organizations. After excellent test results, the Operational Development and Evaluation Force (OPDEVFOR) recommended that the Mk 16 launcher be produced in quantity for fleet use with the 2.75-Inch FFAR. Efforts then focused on developing a combination unit, 2.75-inch FFAR Rocket Container AERO 6A, to serve as both shipping container and launcher. The simplified shipping and launching pod proved so successful in Korea that BuAer ordered it into full production while fleet evaluation was still going on.[70]

Continued gun-camera difficulties kept the Marine Aircraft Wing tests of Mighty Mouse from matching the launcher success. Although 2,000 rockets were fired at ground targets during the first tests in Korea, Patton and Shea returned home in April 1952 with disappointingly sparse documentation.[71] The trip was nevertheless important in that it signaled the station's continuing interest in sending its technical people to study NOTS weapons in everyday


U.S. Navy photo NP/45 LO11358 courtesy Harold Patton

Ordnanceman in Korea loading Mighty Mouse 2.75-inch rocket into NOTS-developed seven-round launcher.

use on the field of battle. The NOTS Advisory Board, meeting that August, urged the station to continue fleet-support activities on a larger scale.[72]

Mice in Combat

The story of the FFAR's successful introduction in Korea well illustrates the benefits of the excellent communication links forged in China Lake's "outdoor laboratories." These ties often remained strong as the military part of the development team moved on to other assignments. Commander Frank G. Edwards, Jr., had come to China Lake in early 1950 with Detachment M, "Team Mike," of Composite Squadron (VC) 35. As Team Mike accomplished the initial ground-target tests of Mighty Mouse at China Lake in late 1952, Edwards became a fervent advocate for the new rocket. So pleased was he with the test results that upon his assignment in early 1953 to *Philippine Sea* as executive officer of VC-35 he immediately began petitioning to get the war trial of Mighty Mouse assigned to Team Mike.

During his tour at China Lake, Edwards had enjoyed a warm, productive working relationship with Newt Ward, associate head of the Aviation Ordnance Department. Now Edwards realized that Ward would be a useful ally in efforts to bring "mice" to Korea. Soon after Edwards arrived in Korean waters, he wrote Ward from a cramped cubicle on board *Philippine Sea*. Describing his experience so far as mostly "general quarters for sunrise and sunset plus 18 hours of waiting each day," Edwards said that he had flown a one night-interdiction run over a Korean beach and spotted more targets than he could use. "Feel fairly sure that they do not consider me a wave of destruction yet," he commented wryly, "but with a little more practice I should be able to scare them as badly as they do me."

His night-flying experience convinced Edwards that Mighty Mouse would be excellent for flak suppression. "Please keep us in mind on the 2.75s," he wrote. "We are hot to go and believe that we can show the rocket off and do credit to it. The pilots that used it at Inyokern are enthusiastic to a man and I think that we can make lots of people want it badly." Joining Edwards in his impatience was Edward "Ed" Chilton, a member of the station's Central Evaluation Group, who was on board *Philippine Sea* in a fleet-support role.

Captain (later Vice Admiral) Thomas F. "Tom" Connolly, who had succeeded Moorer as NOTS experimental officer in July 1952, passed Edwards' letter along to Ellis, attaching a note: "Can't we do anything to increase the present number (1000) of 2.75s going to VC-35? Especially if Cdr. Edwards & Ed Chilton tell us they're hot for more?"[73]

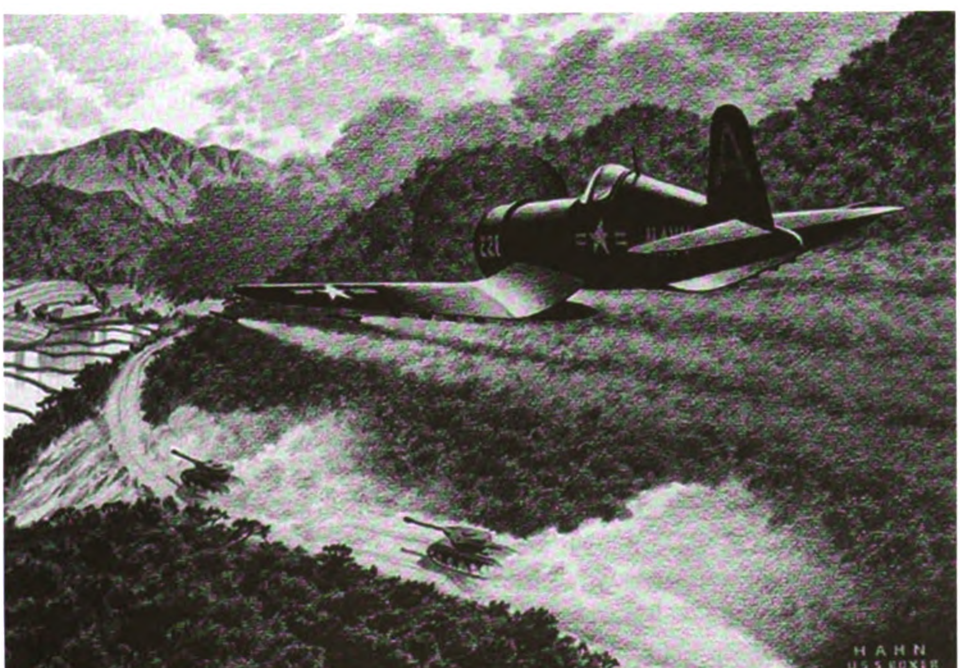
As the China Lake rocketeers worked to clear paperwork hurdles, Edwards awaited the new rockets with growing impatience. He sent Ward another plea:

> Have a few more flights over the beach now and we are more anxious than ever to get the 2.75 rockets. Last night I made runs on around 20 trucks. The 20 MM are good but 2.75 would be better. Total trucks sighted last night IN 2 HOURS were well over 100. We found one train last night and one the night before. HELP![74]

By 4 March Ward had good news: he notified Edwards to expect a small allotment of "some mice and packages to be delivered to you late this month or the first of the next." Even better was the news that NOTS had "just received a letter . . . with 'umpteen' endorsements, the last by BuOrd, concerning supplying these items to the whole Pacific Fleet." Ward estimated that more widespread availability might take six to eight months. In the meantime, he said, "We will be most interested to hear your results when you do get this small allotment for your group."[75]

Lieutenant Commander F. E. Ward, officer-in-charge of Team Mike, was one of the first to try out the new rockets. On a clear, moonless night in late March he took to the skies over the formidable terrain just west of Wonsan, his Skyraider carrying six NOTS-designed pods of FFARs (seven "mice" per package), plus flares and bombs. His experience, as described to a visiting journalist, soon made inspirational reading for the folks back home:

> LCDR Ward swung the heavily loaded plane to the left and began a 'dummy' run.. . . Ward detected the long string of trucks winding its way down from the hills and through the valley. He pulled his plane up just as the lead truck reached the river.
>
> The driver flashed the first truck's headlights across the narrow bridge and stopped short. Apparently he was afraid to cross without lights but dared not use them with the heckler overhead. LCDR Ward made another pass as the vehicles piled up close behind one another. This time a flare from the attacking Skyraider turned the blackness of the valley into daylight. . . . LCDR Ward checked his rocket launching switches and nosed over into a dive. About 30 trucks were like sitting ducks.
>
> The altimeter counted off the descent—1800 feet, 1700, 1600. LCDR Ward's hand gripped the stick tightly. The glowing needle slipped to the predetermined altitude and his thumb snapped down on the red button. All 42 rockets streaked forward and almost instantly the convoy was showered with a barrage of white-hot explosions. Supplies and torn metal rent the area and flames leaped from the truck beds and canopies. One push of the "pickle" and five trucks had been blown to oblivion.[76]



U.S. Navy Art, No. 88-191-BG, by Herbert C. Hahn, courtesy Naval Historical Center

F4U Corsair firing rockets in Korea in close-air support of United Nations ground forces.

An additional rocket shipment arrived in early April, and satisfying results continued. By 9 April Newt Ward heard good news from Edwards: "The mice are beginning to pay off for us." Truck hunting was "just like swatting flies, no strain," he said. Enthusiasm for the new rockets throughout Task Force 77 had reached the point that "Ed Chilton and I have trouble talking about anything except the rockets. Every time we sit down someone eases up to us and wants to know how he is going to get ahold of a few for his squadron to try them out."

Since the pilots had been instructed not to shoot unless they encountered promising targets, aircraft were likely to return to the carrier still laden with rocket pods. But experience increased comfort levels. "They barked at me a little when the first ones came back . . . but they are getting used to it now," Edwards wrote. "All of this information will gradually drift down to you through official channels, but I thought that you would like a little dope on this fine weapon as we go along," he added, concluding his letter with a grateful "NOTS done themselves proud."[77]

Mighty Mouse had proved its destructive capability as an air-to-ground weapon and its ease of handling. Rear Admiral R. E. Blick, Commander Carrier Division 3, immediately recommended a rapid increase in the rocket's production to facilitate general fleet use, and the Fleet Service Activity Unit began visiting aviation ordnance schools, as well as other operating squadrons, to help train fleet personnel in handling, loading, and firing the rocket in its Aero 6A launcher.[78]

As the war in Korea limped through its last weary months, the success of Mighty Mouse was rare good news. After more than three years of inconclusive fighting, the Communists and the allies signed an armistice on 15 July 1953. Neither side had won. The U.S. Navy, however, had gained significant ground in its claim that naval air power was needed to contribute mobility and flexibility in conflict and had disproved the prevailing earlier view that the Navy in war should provide primarily convoy and patrol.[79]

The China Lakers' experiences in direct contact with the operating forces also offered lessons applied to all later conflicts to this day. Station engineers visiting the front demonstrated for the first time the importance of direct observation of NOTS products in use and communication with warfighters in the battle environment. Not only could the visiting engineers deal with many of the problems in real time, but they could also carry precise information about problems back home where necessary redesigns and modifications could be made. The NOTS Advisory Board agreed that fleet support was essential, and in December 1952 the station set up fleet service as an organized, continuous

NOTS Advisory Board meeting, 3-5 April 1952.

At this meeting the board urged expansion of fleet-support activities. Clockwise from center front are Dr. F. W. Brown, NOTS technical director; Dr. C. C. Lauritsen, professor of physics, Caltech; Dr. L.M.K. Boelter, dean, college of engineering, University of California; J. L. Atwood, president, North American Aviation, Inc.; Dr. W. R. Brode, associate director, National Bureau of Standards; Dr. W. H. Rodebush, professor of physical chemistry, University of Illinois; Dr. L. R. Hafstad, Atomic Energy Commission; Dr. H. W. Emmons, professor of engineering science, Harvard University; Captain Levering Smith, NOTS associate technical director; Dr. C. C. Bramble, technical director, Naval Proving Ground, Dahlgren; R. H. Kent, associate director, Ballistic Research Laboratory, Aberdeen Proving Ground; Dr. R. A. Sawyer, dean, Horace H. Rackham School of Graduate Studies, University of Michigan; Dr. F. C. Lindvall, chairman, Division of Engineering, Caltech; C. B. Stevens; Dr. R. W. Cairns, assistant director of research, Hercules Powder Company; Captain W.V.R. Vieweg, NOTS commander; Rear Admiral W. S. Parsons, deputy chief, BuOrd; Dr. H. P. Robertson, Office of the Secretary of Defense; and Dr. L.T.E. Thompson, former NOTS technical director, consultant to Norden Laboratories, White Plains.

activity within the Central Evaluation Group. The major functions assigned to the group were to gather operational and tactical information about weapons in the field, to help military personnel learn how to use new ordnance items introduced into the fleet, and to report back on problems encountered during those endeavors.[80]

Even after its official establishment, the fleet-support group remained small, with Chilton serving as the station's main liaison. In September 1953 the Research Board agreed that the unit's size should stay at three people, two assigned to China Lake and one to Pasadena. At Connolly's suggestion, however, a naval officer would accompany the fleet-support group on major trips.[81] The station's leaders recognized that the civilians involved in fleet support needed to have constant dialog with the experimental officer and his staff.

Years later when Connolly, by then a vice admiral, returned to speak at China Lake's 25th Anniversary celebration, he made special note of that commitment to the operating forces. "I've seen many of you putting professional fatherly arms about the shoulders of the young officers we send to you and that you encounter in the fleet in the operating forces, explaining, understanding their problems and needs, giving as much as you can of your knowledge and interest to solve their problems," he said.[82]

8

Politics and Progress

Even as the Korean conflict continued, China Lake's accelerated work pace encompassed new projects, with a new responsibility for the entire BuOrd rocket R&D program. The desert rocketeers soon discovered that the bureau expected to retain much of the authority for the program in Washington. Higher authority also intervened in the fledgling Sidewinder and OMAR missile programs.

The NOTS mavericks didn't let politics slow them down. Rather they depended on their own strong leadership and technical excellence to make significant progress in systems and concepts.

First Rocket, Then Fuze, Then Feasibility Study

By 1950 technological advances had brought fully operational guided missiles closer to feasibility. Competition among the services and between groups within each service was more fractious than ever, with the issue of missile cognizance no closer to being solved. Among the 35 or so missile projects receiving direct funding support in fiscal 1950, none had achieved an operational missile. The distribution of scarce funding resources caused much unhappiness, but irrelevant projects were not being canceled. Each service complained that the funds necessary for further development were being wasted on the missile projects of the other services.[1]

Although the Committee on Guided Missiles (GMC) of the Research and Development Board discussed the cognizance issue at length, members were unable to reach consensus. The committee therefore recommended in March 1950 that the responsibility for authorizing missile projects be turned over to the Joint Chiefs of Staff. Secretary of Defense Johnson rejected this recommendation as unworkably broad, instead approving a JCS consolidated priority list of missiles that assigned the Air Force exclusive responsibility for developing both strategic and tactical missiles.

This decision was not as significant as it seemed, since BuOrd and the other major players in the missile game still obtained their appropriations directly from Congress, with individual R&D programs often not called out as separate line items. Consequently, Army and Navy organizations could circumvent the priority list by referring to their ongoing missile programs as "studies and designs."[2]

The politics within the Bureau of Ordnance thus met those in the larger political arena, and the Sidewinder project, which had been called first a rocket, then a fuze project, would now be called a study.[3] The task of naming this supposed study fell to Commander Thomas H. Moorer, who arrived on the desert in December 1950 as the station's new experimental officer.

Admiral Thomas H. Moorer, Chief of Naval Operations, 1967.

Moorer, an Academy graduate with a keen interest in technology, had proved his competence as a naval aviator in a variety of assignments to carrier-based, patrol, and bombing squadrons. During World War II he was a Navy flyer helping defend the Philippines against the Japanese invasion. His heroism and leadership qualities earned him an impressive array of medals. At war's end he joined the Strategic Bombing Survey in Japan. He served as executive officer of the Naval Aviation Ordnance Test Station, Chincoteague, Virginia, under Vieweg's command. Moorer was operations officer of Fast Carrier Task Force 87 when Vieweg requested that he become NOTS experimental officer.[4]

Rear Admiral William J. Moran, 1970.

At China Lake Moorer moved into an office already occupied by his second in command, Lieutenant Commander (later Vice Admiral) William J. "Bill" Moran, a decisive young man in the midst of the first of three successful tours at China Lake.[5] The two shared more than office space; their practical approach to problems meshed too. When BuOrd sent word in early 1951 that Sidewinder and the related Optically Maneuvered Aircraft Rocket (OMAR) project needed feasibility study designations, Moorer and Moran looked no further than their phone dials. Moran's number was 71567, Moorer's was 71602. So Sidewinder became Feasibility Study (FS) 567, and OMAR became FS 602.[6] Although Sidewinder could thus continue temporarily as a study project, its acceptance at the highest levels was still needed before it could continue into production and use.

"Kellerizing" the Nation's Missiles

The station's leaders had learned much about missile politics during the ill-fated NOTS AM project. But a year had elapsed since cancellation of the project, and the review process had become even more convoluted. Three important bodies in Washington possessed missile oversight authority: the RDB for reviewing and coordinating development programs, the Munitions Board for coordinating industrial mobilization, and the JCS for defining service requirements. The Weapons Systems Evaluation Group (WSEG), set up in 1949 under joint JCS-RDB sponsorship, was charged with making independent evaluations of the systems under development. Adding to the complexity of the review process was the Guided Missiles Interdepartmental Operational Requirements Group, established in March 1950 to improve coordination of research, development, and procurement among the military services and among the preexisting coordinating bodies.

To this tangled web must be added another skein, one that directly threatened the station's hard-won participation in missile development work. In August 1950 Under Secretary of the Navy Dan A. Kimball recommended that the Secretary of Defense establish an OSD director of guided missiles, a "missile czar," to coordinate RDB, Munitions Board, and JCS positions on the missile programs of all the services. Under Secretary of the Air Force John McCone and Army Major General Kenneth D. Nichols were prominent supporters of this concept, which they envisioned as a "Manhattan Project for missiles," an office powerful enough to eliminate bureaucratic red tape and interservice rivalries.[7]

Just as this idea surfaced, President Truman decided to stop trying to deal with the liabilities accumulated by Louis Johnson during his tenure as Secretary of Defense. The B-36 and flush-deck carrier funding imbroglio, the discouraging course of the Korean conflict, and an acrimonious relationship between Johnson and Secretary of State Dean Acheson were all elements in Truman's decision to ask his Secretary of Defense to resign. Johnson's successor was internationally respected war hero General of the Army George C. Marshall, who became the nation's third Secretary of Defense in September 1950. In one of Marshall's first official actions in this post, he accepted the President's recommendation to select Kaufman T. Keller, chairman of the board of Chrysler Corporation, as director of guided missiles.

A portly "tin-bender" with brusque demeanor and grizzled brushcut hair, Keller had strong opinions about what was wrong with the nation's weapon programs. He formally accepted the missile czar position on a part-time unpaid basis in October 1950, but only on the condition that he be given a knowledgeable military deputy. Furthermore, he wanted a guarantee that his ideas would be influential at the highest levels, and he made it clear that he would quit if his recommendations were not accepted.[8]

Courtesy U.S. Naval Museum of Armament and Technology

Kaufman T. Keller.

One of Keller's conditions was fulfilled admirably when Nichols became deputy director of guided missiles. Nichols was unusually well qualified to provide the insider's perspective: he had been in the inner circle of atomic-energy policy ever since he joined the Manhattan Project in 1943. As chief of the Armed Forces Special Weapons Project since 1948, he was a member of several influential oversight groups, including the GMC and the Military Liaison Committee.

When Keller and Nichols began discussing their new responsibilities, they quickly realized that an organization analogous to the Manhattan Project was not feasible, given the prerogatives of the powerful missile stakeholders. The two men agreed that trying to stop ongoing missile R&D efforts would be futile. Instead, they would exercise the necessary control by directing which missiles would go into production. To that end they set up a charter that appeared to give the director of guided missiles a strictly advisory role. In reality the missile czar wielded considerable authority, much of it stemming from a directive issued by the assistant secretary of defense (comptroller) that stipulated that funds for production or procurement of guided missiles could be obligated only "in accordance with production and facility programs that have been recommended by the Director of Guided Missiles and approved by the Secretary of Defense."[9]

Keller vigorously advocated encouraging industrial participation in missile-development programs and pushing these programs into the production phase as rapidly as possible. Both his champions and his critics termed his approach "Kellerizing." Although his decisions were efficient in the sense that they were made with minimum delay and paperwork, his critics complained that those decisions were eccentric and arbitrary. Leaders of government and university laboratories saw the controversial Keller as prejudiced in favor of industry, while Air Force and Navy officials viewed him as biased toward the Army, partly because of his close working relationship with Nichols.[10] Neither of these perceived biases was likely to work in favor of NOTS and Sidewinder.

China Lake and the Missile Czar

The new missile czar began a series of visits to all U.S. guided-missile programs, gathering information to help him decide which missiles should be produced and which should be canceled. Keller first visited NOTS in February 1951 during a fact-finding trip to West Coast guided-missile installations. He was not impressed with the independent ways of China Lake scientists and engineers.

His visit overlapped with a tour of NOTS facilities by 44 members of the RDB Committee on Ordnance, headed by Dr. J. A. Hutcheson, an old friend of Thompson's and a once and future member of the NOTS Advisory Board.[11] The FS 567 designation was mere days old at the time of this visit, and the bureau's Guided Missiles Branch (Re9) had nervously advised Vieweg that the Sidewinder project, if it were mentioned at all, should be referred to only as a feasibility study.[12] As a result, instead of the straight talk about Sidewinder that Keller expected, the missile czar and his six-member entourage were included in a more generalized program designed to show the spectrum of station functions to the RDB committee members. Since Sidewinder could not be part of these presentations, NOTS management instead used the opportunity to work in a bit of politicking on behalf of a significant testing asset in its design phase—the Supersonic Naval Ordnance Research Track (SNORT).[13]

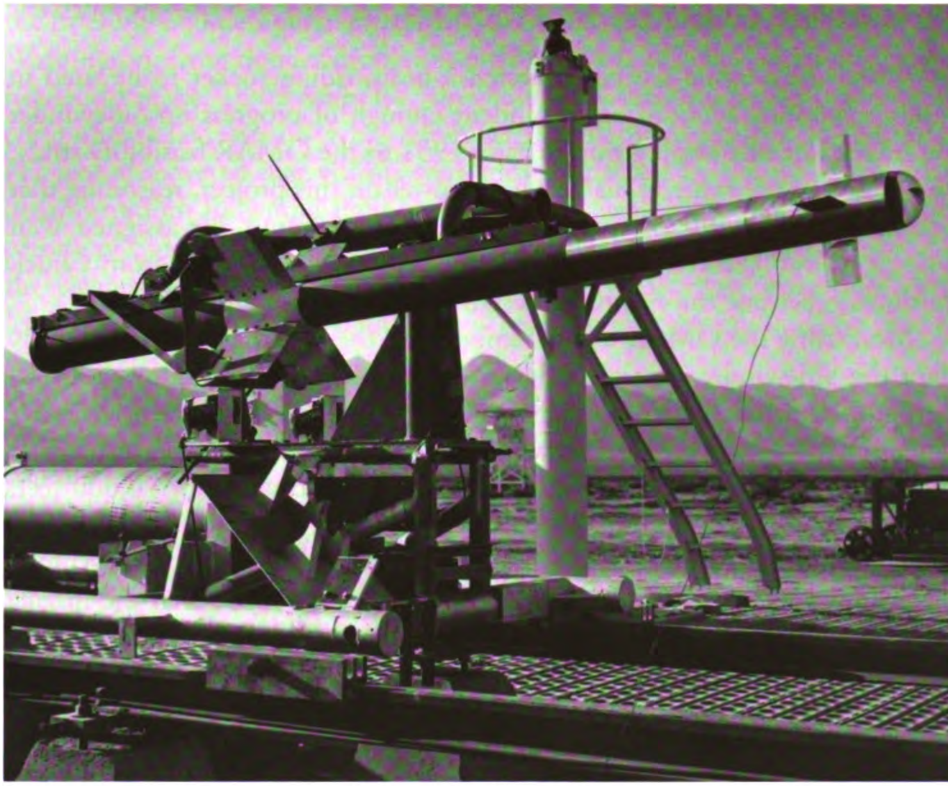
In early August Keller returned to the desert, accompanied by Nichols and two other high-ranking staff members. The station was under no gag order this time. In a two-day agenda focusing exclusively on Sidewinder, the visitors learned that technical feasibility was largely established, but that much development work remained to be done before production could begin. Keller reacted negatively to China Lake's in-house, untried program; he especially disliked the parallel development of alternate seekers, which he saw as a wasteful expenditure of time and money. He came away from the review convinced that Sidewinder was a "boondoggle." The station should concentrate on testing, he said, and leave the development work to organizations possessing more industrial experience.[14] McLean in turn attempted to convince Keller that "research leads to requirements. It does not follow from requirements."[15] Nichols, also dubious about the alternate-seeker approach, later recalled that Keller was intrigued with the project but urged the NOTS team (in what McLean must have viewed as preaching to the choir) to "keep it simple."[16]

After Keller's second unsatisfactory visit, Thompson wrote BuOrd Chief Rear Admiral Malcolm F. Schoeffel, expressing concern about "what appears to be, on the part of some high-level people in the country, almost a dislike for the operations of a center set up as NOTS is." Fearing not just for the Sidewinder project, but also for the continued existence of the precepts upon which the station was founded, Thompson wrote:

> What these people don't seem to realize is that better industrial work will be done, and the volume will be greater I think, if the Military Establishment keeps its hand in the actual development work in parallel with its work on the "Operations" side (the combat field) because the Military will then have better "requirements" and better judgment, and will offer more effective collaboration with industry toward getting products that work.[17]

As station leaders fought for Sidewinder's continued existence, team members continued their obsessive night-and-day schedule. The first free-flight test of the missile's airframe occurred on the Lark ramp on 9 October 1950, just four days after BuOrd officially authorized the Sidewinder project. By the following May, seven more tests with dummy control sections had been conducted. At the same time all components of the guidance-and-control section had been extensively bench-tested. The hot-gas control servomotor and the rolleron system had been demonstrated successfully during flight tests in March of two "sunseeker" rockets sled-launched from Baker-4 Range and instrumented to turn toward the sun after launching.[18]

The target survey work also continued, with the Naval Air Facility supplying five target aircraft to represent various types of infrared exhaust patterns. During the first half of 1951, 24 airborne tests allowed Larry Nichols and his Research Department colleagues to refine their scanning techniques and to prove that aircraft could be detected against daytime sky by infrared means. The team also found that a multislit reticle was effective in reducing interference from background radiation signals. Test results included detection



U.S. Navy photo NP/45 LO 032018

First free-flight test of Sidewinder, EX-0 airframe, on Lark launcher, 9 October 1950.

of signals out to five miles with an F9F jet target and out to 11 1/2 miles with an F8F propeller-driven fighter painted dark blue.[19]

When simulator analysis showed that the pneumatic precessing schemes used in the C and E types of seekers were not feasible, McLean canceled the work on these two versions.[20] Round-the-clock work on the A and B versions continued. By June 1951 NOTS and Avion personnel had handcrafted a laboratory model of the A seeker, and in controlled laboratory conditions the seeker had successfully tracked a six-watt light bulb. A laboratory model of the B seeker, built by Luc Biberman, Ed Swann, and a team of sharp engineers demonstrated similar tracking ability.[21]

McLean was feeling the pressure to progress beyond seeker tests on the roof of Michelson Laboratory and sled tests on B-4 Track. He wanted to demonstrate the complete missile's performance in flight as soon as possible—but he also realized the importance of having an early success once air firings of the "bird" began.

Beam-Riders, Cigarettes, and Committees

When the Marine Corps requested a beam-riding rocket to be used in close air support, McLean was confident enough of progress on Sidewinder that he reassigned a small group in early 1951 to the OMAR feasibility study. He decided to use some of his best brainpower on this project, reasoning that a quick solution to the Marines' problem could be found. He assigned Walt LaBerge to lead the OMAR team, with indefatigable assistance from Chuck Smith, who became the electronic design engineer for the project.

Motivating the OMAR team members was the idea that they could easily adapt the Sidewinder control package (servo motor, gas generator, electrical alternator, and magnetic amplifier) to operate with an optical receiver on a standard five-inch rocket. A pilot would fire OMAR from a single-seat fighter aircraft to deliver a 30-pound warhead a maximum distance of 10,000 feet. The pilot would project a coded optical beam on a ground target, and the missile would then fly down the beam. Four backward-looking lead-sulfide cells would pick up guidance information from the beam so that the missile would be constantly aware both of its roll orientation and of its position and velocity relative to the beam axis. An electronic circuit in the missile containing about a dozen vacuum tubes would keep OMAR flying straight down the beam axis to the target. The servomotor for controlling the trajectory would be the same as for Sidewinder.[22]

The first model of OMAR's optical system contained a single focusing lens, which did not produce a sharp image on the lead sulfide cell. A double-lens system demonstrated a more satisfactory image. During the next few months the first experiments with breadboard components showed that under ideal conditions a pilot could track a target quite accurately and that precise guidance information could be transmitted and received at the required ranges.[23] Just as with Sidewinder, however, the small OMAR team could proceed only so far with existing resources. Detailed design, testing, and coordination with other activities would all require additional funding. LaBerge began accompanying McLean on his briefing trips to Washington.

While the station waited anxiously for K. T. Keller's other shoe to drop, a procession of official visitors arrived to study Sidewinder and OMAR. Despite McLean's natural reserve, he could be a consummate salesman. He realized the importance of the personal attention he must pay his visitors, each of whom had a voice in clarifying the question of whether Sidewinder and OMAR should be included in the handful of missile projects to be selected for continued support. Only the energy McLean poured into the programs kept the briefings and demonstrations he was obliged to give, in China Lake and in Washington, from detracting significantly from the technical decisions he still needed to make. To be ready for "show-and-tell" sessions, he kept the missile components laid out on a big felt-covered table in Michelson Laboratory.[24] He soon discovered that visitors were most impressed by a simple but showy demonstration: he would light a cigarette and walk back and forth in front of one of Sidewinder's seeker models, which would track the heat source of the cigarette's glowing end. "McLean was always demonstrating that," Rod McClung recalled. "I was afraid he was going to take up smoking, he used so many cigarettes."[25]

McLean and Wilcox believed that sufficient data had been accumulated on Sidewinder's components to show that the remaining technical problems could be solved. In May 1951 McLean wrote Re9 asking for funds to procure a supply of major components. In response to this request, Re9 scheduled a September GMC review of the Sidewinder program. Rather than wait for the review, McLean decided to increase the information flow in the meantime, and on 13 July, he published a report, *Status of Feasibility Study 567*, in which he predicted that a complete Sidewinder could be produced for less than a thousand dollars.[26]

During a trip to Washington on 18–22 July, LaBerge gave a briefing on OMAR, and McLean demonstrated the B-seeker model to Rear Admiral G.B.H. Hall, director of the OPNAV Guided Missiles Division. McLean explained that the innovative elements of both missiles—the integrated power supply and servo as well as the rollerons—represented "substantial gains in performance and reductions in cost over the equipment required to perform the same functions in other missiles." Every effort at China Lake, he assured his influential listener, was concentrated on flight tests and modifications to improve a still-erratic steering mechanism. McLean urged Hall to adopt the position that seeker development was far enough along to begin contractor indoctrination and procurement of nonstandard parts for Sidewinder's first 200 units.[27]

Hall was impressed. The following week he brought six members of his staff, as well as representatives from BuOrd, the Naval War College, and Marine Corps Headquarters, to China Lake to see Sidewinder demonstrated on its home turf.[28] Design difficulties had delayed both the A and the B seeker so that neither was ready for free-flight testing. But McLean was able to provide his guests with a suitably impressive field demonstration modeled on his success with cigarette tracking. Rod McClung and David J. "Dave" Simmons, with the help of Ted Whitney and Larry Nichols, modified an SCR-584 radar tracking pedestal to allow IR target tracking. This device allowed visitors to view flyover-tracking tests and—perhaps more memorably—to walk around the IR tracker with lit cigarettes and observe the tracking for themselves.

Members of the GMC's Panel on Guidance and Control came to the desert on 11 September, with the stated intention of investigating the "alledged [*sic*] advantages of simplicity and early availability" of both Sidewinder and OMAR, of determining whether overlap existed with other missile developments, and of making recommendations to the RDB based on these findings. The panel members, still not convinced that NOTS products were ready for full support, recommended not funding additional hardware until the station provided additional experimental data.[29]

McLean had scarcely put the cigarettes away when on 19 September more high-level visitors showed up, this time a group of renowned scientists participating in Project Metcalf, one of a series of "summer studies" conducted under the Navy's sponsorship that employed prominent university professors and industrialists in intensive scrutiny of tough R&D problems. These inquiries typically occurred in the summer, a convenient time for the academicians involved. Project Metcalf was organized through an ONR contract with Harvard University to study the military role of infrared detection and making recommendations among the Navy's competing infrared missile projects. Influential Harvard professor Dr. Donald F. Hornig (later the President's science advisor) led the group.[30]

McLean attached special importance to impressing the Metcalf group, which he believed had been formed specifically to recommend a choice between Sidewinder and a competing seeker system, AN/DAN-3, which BuAer intended to incorporate in the Sparrow missile.[31] This seeker, under development by Aerojet Engineering Company, had bitter significance for McLean, who could trace the AN/DAN's lineage to General Tire and Rubber Company work in 1947 and 1948 on the NOTS AM.

Two of features of AN/DAN especially rankled McLean. The first was a "method of obtaining the precession from the error signal directly without resolving it into components," which McLean noted "was suggested by me and is covered in my notebook under the date of 19 November 1947." The second, "the use of a spherical central race for a ball bearing which makes it act as both the gimbal system and the support for a gyro wheel," McLean remembered as having been suggested to GT&R by Jesse Watson, whose work on the C version of Sidewinder's seeker head had involved use of "a similar system in supporting gyros to telemeter spin orientation in spinner rockets." Aside from these two NOTS-originated innovations (both of which the station had since improved on), McLean could find little to recommend AN/DAN-3, which he pointed out "still has the advantages as well as the mistakes which were present in the unit at the time of the GTR contract."[32]

Hornig and his group liked what they learned at China Lake, and the Project Metcalf report identified Sidewinder as a promising application of infrared technology. Perhaps as useful to NOTS was a phone call Hornig is reported to have made to high-placed friends in Washington when he learned of Keller's opposition to Sidewinder.[33] His support was crucial, since several of the military officers assigned to the RDB believed that NOTS should adapt the AN/DAN-3, rather than coming up with its own missile. "The NIH 'not invented here' attitude was suggested as a reason why the DAN 3 was not considered," reported Moorer, after a series of meetings in Washington. "Apparently none of the R&DB members are familiar with the history of the project."[34]

On 11 October the entire GMC came to the desert, viewed a demonstration of the B-head tracking model, and returned to Washington to recommend that RDB approve funding for Sidewinder, primarily so that additional hardware for testing could be procured. Approval from the full RDB soon followed.[35] The presentation to Hall also paved the way for a memo BuOrd received in October from OPNAV, requesting that Sidewinder and OMAR be classified as guided missiles. These related events signaled better days ahead. On 9 November BuOrd officially reassigned primary coordination responsibility for Sidewinder and OMAR to Re9, abandoning the fiction that the two projects were feasibility studies. The Ammunition Branch (Re2) and the Aviation Ordnance Branch (Re8) turned over appropriate Sidewinder and OMAR files to Re9.[36] In late November Bureau Chief Schoeffel released $1.5 million to be split between Sidewinder and OMAR in fiscal 1952, with a promise of another $1.6 million (again to be split between the two projects) in fiscal 1953.[37] The message marked a turning point in bureau funding support, and from that time onward, Sidewinder had the money it needed for further development.

In Charge of the Rocket Program—Maybe

Even as Sidewinder work absorbed an increasing number of employees, the aerial rocket program continued full steam ahead, with the rocketeers relying on the station's instrumented ranges and superb test pilots to try out new and improved rockets.[38] With Sidewinder yet to prove its feasibility and other missile efforts plagued by technical difficulties, rockets remained a critical part of the nation's arsenal. In May 1951 BuOrd Chief Schoeffel issued a memorandum assigning China Lake the technical direction of the bureau's entire rocket R&D program and giving the station the authority to "Plan and keep current a comprehensive, scientific and technical program designed to maintain balanced and coordinated research, and effective development including design, engineering and process development." The bureau would continue to furnish NOTS with military requirements, to establish and prioritize broad areas of program emphasis, and to approve contract awards and task assignments to other field activities.[39]

Station leaders greeted China Lake's new responsibility warily. "It looks nice on paper, but it does not work that way," Ellis said. What was needed, he continued, was information from the fleet on what was lacking and information from the technical experts on what was possible. "BuOrd has to serve as middleman." Other Research Board members asked how NOTS could best guide such a broad effort, and Fred Brown suggested that the time was ripe for a process similar to the Torpedo Planning Advisory Committee (TORPAC) effort, a planning committee with the inevitable acronym ROPAC.[40] The idea met with resistance in BuOrd, where the prevailing view was that Schoeffel's memo in May had already given NOTS sufficient guidance.[41]

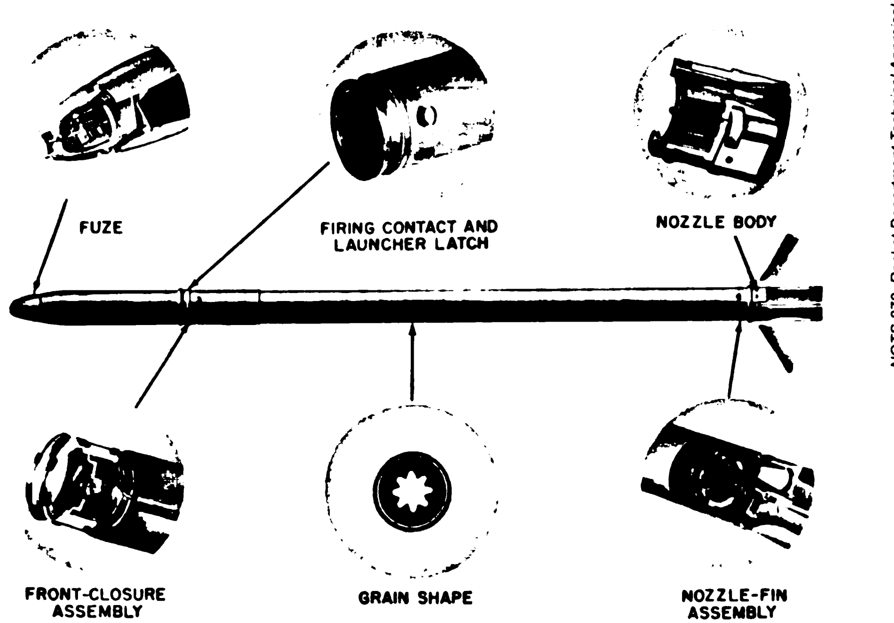
The push for more autonomy was motivated at least in part by frustration among China Lake rocketeers, who wanted to develop a 1.5-inch air-to-air rocket. A station attempt to flex its supposed program-management muscles resulted in not just failure to win authorization for the 1.5-inch rocket, but also a temporary threat to the continued development of the 2.75-inch FFAR, already being produced by the hundreds for experimental evaluation.[42] The station had begun work on the 1.5-inch rocket at the invitation of North American Aviation, which had requested help in developing a solid-propellant rocket. The prospect of a new rocket project was timely from the standpoint of the workload at NOTS, since most of the labor hours devoted to development of Mighty Mouse would be released for other work as soon as that rocket moved into full-scale production. In a 19 November 1951 meeting of the Research Board, Ellis represented the Rocket Department position in favor of the 1.5-inch rocket development. The rocket, he said, would "fill in the gaps" in the Navy's arsenal.

Since the Navy's new aircraft were fighters rather than bombers, Ellis said, an important consideration was rocket size. The new rockets would be short (only 24 inches in length), as well as small in diameter, so that an aircraft could stow about six times as many as was possible with the 2.75-inch FFAR. Ellis also pointed out that NOTS was in a better position to develop the rocket than was North American, which could get help with the propellant from other industrial firms, but which "must surely realize that they would have to have the assistance of NOTS on the head and fuze combination." After weighing the relative advantages of the 1.5-, 2.0-, and 2.75-inch rockets, the Research Board generally favored Ellis' position, but decided that the matter should be considered further, "perhaps from a political standpoint as well as potential performance."[43]

Information on the political part of the decision came with Moorer's next visit to Washington, where he discovered little support for either the 1.5- or the 2.75-inch rocket. His contact in the Armor, Bombs, Projectiles, Rockets and Ballistics Branch (Re3) pointed out that NOTS was already in receipt of a directive to proceed with a 2.0-inch rocket 48 inches in length and that the bureau and CNO had agreed "that the Navy's purpose will be best served by one rocket." Rear Admiral John A. Snackenberg, deputy chief of the bureau, urged Moorer to carry the message to all NOTS technical personnel to "move ahead as quickly as possible to get hardware in use" and "to avoid letting 'the perfect be the enemy of the good.'"[44]

After Moorer brought this news home to China Lake, the Research Board prudently decided in early 1952 to cease work on the 1.5-inch rocket, particularly since nobody at NOTS wanted to jeopardize progress on the 2.75-inch FFAR. The experience hardened Brown's resolve to press the bureau once again to support a ROPAC exercise. He gained agreement from Schoeffel "that this area of ambiguity should not continue, and that a definite bureau policy is necessary."[45] With that informal encouragement from BuOrd, NOTS went ahead with its reassessment.

The bureau's priorities in the small-caliber rocket program having been made clear, the station pulled its 2.0-inch rocket program off the shelf where it had languished since the start of the Korean conflict. In addition to the bureau imprimatur and a catchy new name, Gimlet, the 2.0-inch rocket now had the opportunity to capitalize on several technology advances, including considerable additional knowledge in small-caliber rocket-motor design, as well as NOTS-developed mesa-burning propellants.[46] Gimlet's thin-walled aluminum-alloy motor tube and folding fins owed a debt to the 2.75-inch FFAR. In addition, members of the Rocket Department's fuze group under Bob Olsen dramatically reduced the scale of their design for the 2.75-inch FFAR's nose fuze, retaining all of its features in a thumb-size package. With this fuze, plus an innovative



2.0-Inch Folding-Fin Aircraft Rocket (Gimlet).

"cookie-cutter" knife-edged warhead, Gimlet proved capable of penetrating and exploding 18 to 30 inches inside the predicted heavy aircraft structure. The rocket thus rivaled Mighty Mouse in the damage it could do to aircraft [47]

Pat Patton, head of the Rocket Department's Projects Division, delegated responsibility for the Gimlet program to small-caliber rocket expert Francis M. "Frank" Fulton. A sharp engineer from Oklahoma, Fulton was a big man with an equally big enthusiasm for tinkering. His well-equipped home machine shop was evidence of his round-the-clock fascination with the way things worked.[48] Patton recalled that Fulton came up with "some damn clever stuff for the Gimlet," specifically an ingenious new way to hold the nozzle-fin subassembly and the front closure onto the motor tube. The aluminum-alloy motor-tube wall of Gimlet was too thin to tolerate the machined groove and lockwire combination used on the 2.75-inch FFAR. Fulton decided to use pressurized rubber to crimp down tabs, an operation that also sized the motor tube to ensure a good O-ring seal. The new method not only solved the practical problem of joining the tube to the nozzle and warhead adapter but also helped the rocket to fly straight.[49] The crimping method of assembling the rocket's motor also enhanced the rocket's producibility. Machining the motor tube became a simple matter of cutting the tube to length, with the crimping operation making unnecessary the close manufacturing tolerances required in other methods of attachment.

Fulton also dreamed up a combined detent and ignition contact band that reduced internal copper wire so much that an estimated 400 miles of wire per month were saved during the rocket's mass production.[50] An important performance feature of the modification was that the wires no longer needed to be ejected on launch, thus eliminating a potential hazard to aircraft engines and windscreens.

Like the improved grain for Mighty Mouse, the internal-burning N-5 propellant grain for Gimlet had an eight-point star perforation. A spiral-wrapping machine encased the grain in tape to inhibit burning. In 1953 Pasadena Annex employees of the Explosives Department's Central Engineering Division dramatically improved the wrapping process by inventing a continuous-spiral-wrap machine. The new machine, soon in daily use at all mass-production facilities producing grains for the 2.75-Inch FFAR, allowed propellant plants to turn out several thousand grains per shift, a great advance over the several hundred grains per shift under more labor-intensive methods.[51] Annex employees built on the continuous-grain idea to come up with an even more efficient process involving rapid extrusion of the inhibitor in a uniform layer onto the grain. After the new process proved its worth on experimental equipment, NOTS developed a full-scale prototype production facility for continuous-extrusion inhibiting.

More Gimlet improvements came as China Lakers conducted track and ground launches and air firings from several different altitudes. In mid-1954 an FJ-2 Fury aircraft equipped with the Mk 16 fire-control system fired a 19-round Gimlet salvo at an F6F drone from 500 yards off the tail. Designed to function as an aerial shotgun, Gimlets sprayed out in a cone pattern to cover the target. In this test, a round found its mark, and the target drone spiraled to the desert floor. Gimlet had proved that it was compatible with the other components of a fighter weapon system.[52]

Rocket Mailing Tubes

China Lake's rocketeering success depended not only on the rocket components but also on the launchers. The station began an experimental task in October 1952 to demonstrate the feasibility of adapting the innovative plastic-coated disposable launchers used during the 2.75-inch FFAR's successful demonstration in combat into a four-round launcher that could also be used as a shipping and handling container for 5.0-inch rockets with folding fins.

As with the smaller Aero 6A disposable launcher that had been developed for Mighty Mouse, this launcher's nose and tail fairings were paper cones that could be jettisoned to lighten the load and improve the maneuvering capability of the host aircraft on its homeward flight.

After a test and redesign cycle at NOTS, a second experimental four-round unit demonstrated that rockets could be fired without damage to the tubes or supporting structure. Century Engineers, the launcher production contractor, then manufactured four prototype Aero X10A launchers with a configuration identical to that of the second experimental launcher. This design further demonstrated that the paper launching tube could withstand rough handling, static loading, and rocket firing tests.[53]

Development of the 19-round launcher Aero 7 began at NOTS in 1953 immediately following the work on the seven-round Aero 6A launcher. Herbert T. "Ted" Lotee, Steven M. "Steve" Little, Orson L. Mitchell, Ray Boss, Sydney "Sid" Shefler, and others in the Rocket Department also applied the mailing-tube concept to a launcher for the smaller Gimlet. Salvo firings on NOTS ranges tested not just the rocket but also a cylindrical launcher mounted under the air intake of the aircraft.[54]

Not all tests were successful. Little, then head of the Rocket Department's Aircraft Launcher Section, remembered one Aero 7A incident in early 1954. His section was called on to assign two pods to Douglas Aircraft Company for flight tests on the batwing Douglas XF4D Skyray at Edwards Air Force Base. The pods, each filled with 19 dummy weighted rounds, were mounted on Aero 14 bomb racks, which Douglas manufactured for the sturdy AD-4 Skyraider. "It was believed by Douglas that the Aero 14 on the XF4D could carry the AERO 7A," Little recalled. "Wrong! The two rocket pods and attached racks are still somewhere out on the desert." According to Little, Edward H. Heinemann, the company's chief engineer and aircraft design genius, then declared that Douglas would leave the bomb-rack and rocket-pod business to BuAer.[55]

The XF4D next appeared with drop-down belly doors to which the NOTS three-round 2.75-inch FFAR clip launchers attached. Little and his group worked on several types of clip launchers: a single-round clip for Zuni, a six-round clip for Gimlet, and even a clip-launcher design for a proposed folding-wing version of Sidewinder. The BuAer involvement in the bomb rack business soon resulted in the Aero 28 bomb rack, which Little termed the key element in wing-rack standardization for operational aircraft. "Before that, various manufacturers built their own racks to suit the design of the aircraft. That all ended with the Aero 28," said Little. "The word was out. 'You want

U.S. Navy photo LO 21369, courtesy Maturango Museum Ernest George collection

China Lake-developed 19-round disposable rocket launcher.

Orson L. Mitchell (right), head of the Rocket-Launcher Branch of the Rocket Development Department's Ordnance Components Division, shows the launcher to visitor Congressman Craig Hosmer (Commander, USNR), September 1956.

to build aircraft for my deck, you use my bomb rack.'" The new Aero 28 rack design caused NOTS to redesign the 19-round Aero 7C rocket pod. After a final test in which a launcher with "hot rounds" survived a rail-car fire without conflagration, NOTS ordered a preproduction lot of the new pods from Century Engineers.

Because carrier landing by an aircraft still carrying hot rounds was out of the question, all 19 rounds needed to be fired from each pod. That made design of the pod intervalometer, the device controlling the interval of fire, critically important. Century Engineers designed an intervalometer that pair-fired the rockets from opposite sides of the pod to reduce the total firing time to a few milliseconds. Ivar Highberg, head of the Test Department, "did his best to fail the puny looking plastic intervalometer during the Aero 7C production design release meeting by slamming it on the table with full force," recalled Little. The device, stronger than it looked, survived the "Highberg test" unscathed.

By 1957 the pods had moved from the R&D stage into production. A demonstration over Armitage Field that April wowed the national press when an AD-5 Skyraider swooped down on its target to fire a swarm of 194 FFARs—a new record—in a single pass. A mere four months later, the *Rocketeer* reported that the Air Force planned to procure 34,000 of the launchers under the designation LAU-3/A and that BuAer was already procuring 45,000 Aero 7Ds from the Be-Ge Manufacturing Company in Gilroy, California. "I don't believe any other NOTS or NWC weapon has ever been released for a first time production of such a quantity," said Little.[56]

The station also developed a lightweight 37-round launcher, weighing no more than its predecessor. Several of these launchers could be loaded on an aircraft at once, allowing the host aircraft to carry as many as 400 to 500 rockets at a time. This rocket-launcher combination was an economical application of the "aerial-shotgun" approach—relatively unsophisticated, but economical and effective against its intended targets.[57]

Changing Emphasis in Medium-Caliber Rockets

The station's rocket work also encompassed the development of improved medium-caliber rockets. China Lake's air-to-ground replacement for the HVAR of World War II was the 5.0-Inch High-Performance Air-to-Ground (HPAG) Rocket, which had a light aluminum body and fins. In 1950 work had begun on adapting folding fins HPAG. The experimental design of the 5.0-Inch High-Performance Air-to-Air (HPAA) incorporated an HPAG rocket and FFAR folding fins.

Station rocketeers also worked on the 5.0-Inch High-Performance Air-to-Water (HPAW) rocket, essentially an HVAR with a new head shape to reduce transverse forces at water entry. But tests with various modifications repeatedly demonstrated that the rockets became useless when they smashed into the water surface. One possible solution involved welding the rocket's head to its steel motor, but that solution put HPAW right back into the "too heavy" category so that performance was only marginally better than that of the original HVAR. In 1950 CNO accepted on BuOrd's advice a redesigned HVAR with an EX-9 head (shaped for underwater application) as an interim air-to-water rocket. Work thereafter on the HPAW version was confined to applications of its head-motor juncture technology to other rockets.[58]

Shipboard salvo of 5.0-Inch High-Velocity Aircraft Rockets, May 1954.

Work on the HPAA also ceased as NOTS rocketeers realized that a short time to target for relatively near targets was more important than high velocity for distant targets. They also discovered that the VT fuze of the HPAA armed at a range that would be too long for accurate aiming. A bureau-directed rocket reevaluation of late 1951 and early 1952 resulted in the Medium-Caliber Air-Launched (MESCAL) program, which focused efforts on rockets capable of hitting their targets at distances compatible with the VT fuze.

After experience in Korea exposed the need for HVAR improvements, the bureau stipulated that redesign avoid significant changes in the propellant grain, with its known ballistic qualities and well-established production facilities. The station then suggested a reduction in motor-wall thickness. The Improved Performance Aircraft Rocket (IPAR) was designed to use lighter construction, incorporating a thin-walled motor tube with a thickened forward section that could be threaded to permit attachment of the head. Tests of the IPAR design demonstrated a velocity of 1,700 feet per second, 400 feet per second faster than the velocity HVAR could attain. The station completed a design study of an Improved Performance Folding-Fin Rocket (IPFF) in 1952.

As a result of the rocket reevaluation, however, the station soon dropped the IPAR and IPFF alternatives in favor of the more promising 5.0-Inch High-

Harold H. Patton and members of the rocket team.
Enjoying a 1951 Christmas party in a corridor of Michelson Laboratory are employees of the Rocket Department's Project Division, including Patton (center right, wearing glasses) and James C. "Jim" McDonald (at left, holding "microphone"). The "rocket" is actually a dummy cobbled together as a party prop.

Performance Folding-Fin Rocket, on which the Rocket Department's Project Branch C (the group in charge of medium-caliber rocket developments) began work in 1953.[59] James C. "Jim" McDonald, the head of Branch C, was the engineer responsible for the HPAG and HPAW program. He and Sid Shefler, who became the project engineer, came up with a simplified single-nozzle folding-fin design for a new rocket they named Zuni after the famous tribe of the American Southwest. From the start Zuni showed promise as a replacement for the HVAR for air-to-ground use.[60]

Even as emphasis in the station's medium-caliber work shifted toward Zuni, the bureau sought more information on the tactical implications of a long-burning, high-terminal-velocity rocket. Consequently, in February 1954 Air Development Squadron Three test-fired 500 HPAGs and 500 HVARs at the Naval Air Station in Atlantic City, New Jersey. The rockets' fixed fins were an operational drawback that ruled out fleet introduction, but BuOrd believed that the tests would provide information important to the design of other rocket motors. The pilots reported that about 10 percent of the HPAG rockets "pinwheeled" in flight. Nevertheless, at slant ranges between 1,000 and 5,000 yards HPAG demonstrated significantly better accuracy than did HVAR.[61]

Although HPAG and several other NOTS-developed medium-caliber rockets never entered the fleet, experience gained with these rockets lived on in improved designs. In HPAG's case, the rocket's motor was modified with folding fins and an X-8 propellant grain to become the propulsion unit for the Zuni rocket. With somewhat fewer modifications, HPAG was also the propulsion unit for Sidewinder and several other systems.[62]

Failure Turned to Success

An inevitable part of the RDT&E process is the project that fails despite the best efforts of all concerned. But occasionally a fresh approach can rescue a failure. Such a project was the Weapon A subcaliber round development begun in 1950, when fleet acceptance of Weapon A appeared to be a matter of a few minor improvements. The idea behind the subcaliber training round was that it would replicate actual conditions as closely as possible, but be smaller than Weapon A itself, which even in its unarmed version was heavy enough to damage a submarine hull on impact.

The idea of developing inexpensive substitutes for training use at first seemed promising, but the subcaliber rounds proved unsatisfactory because, as Barney Smith, head of the Surface Weapons Division, explained, "They could never be made to exhibit the same ballistic characteristics and invariably screwed up the ballistic tables."[63] Attempts to lower the spread of rounds around the impact point were not successful, but BuOrd authorized mass production under the belief that factors contributing to excessive spread would cancel each other out in production. That hope turned out to be overly optimistic. Early field tests of the station's 1,000 initial-production rounds demonstrated that range and dispersion were greater than for Weapon A. By early 1953, all concerned agreed that the first subcaliber round was not a success.[64]

Station leaders also questioned whether NOTS work on Weapon A itself should cease. In February 1952 Rex, the organization responsible for planning, coordination, and analysis within BuOrd's Research and Development Division, put together a list of projects proposed for bureau cancellation in Fiscal Year 1953. Fred Brown and Levering Smith brought home a bureau draft that caused consternation at NOTS. The draft proposed a $4-million cut of station programs, with the lion's share to be absorbed by specific rocket and torpedo programs. The list contained one item welcomed at China Lake, however: a recommendation to stop work on Weapon A until completion of fleet evaluation. As Ellis noted in his written reactions to the Rex draft, that action had been "repeatedly recommended by personnel of this Station."[65]

A report soon came in from fleet tests that the round became so unstable when it was launched at an angle to the wind that it fell into the water sideways. Acting on the suggestion of Highberg, the China Lake rocketeers were able to increase the weapon's stability by simply changing the arming propeller's direction of rotation.[66] With failure thus turned to success, by early 1955 NOTS had redesigned the 4.0-inch subcaliber Weapon A to increase its range and had delivered 1,400 rounds to the fleet.[67]

Liquid-Propellant Innovations

While the first priorities at NOTS during the years of conflict in Korea were products that could be used immediately in battle, other efforts begun during those years brought important postwar accomplishments. One such program was the 5.0-Inch Liquid Propellant Aircraft Rocket (LAR), which built on concepts developed before and during World War II by German scientists at Peenemünde. The Germans had developed several rocket motors that capitalized on the performance advantage of liquid propellant over a comparable volume of solid propellant.

During the closing days of war in Europe, the U.S. government established Project Paperclip to transfer German innovations in science and technology through the expedient of importing not only the documentation but also the brainpower behind those innovations. Under the provisions of Project Paperclip, some 600 German scientists, including about 130 rocket specialists, emigrated to the United States.[68]

The circumstances that allowed NOTS to capitalize on Paperclip expertise involved Levering Smith, then assigned to BuOrd with the rank of commander and destined to take his next tour at China Lake. He was assigned the task of reviewing a mass of Peenemünde documents that gave detailed information on successes and failures in German weapon developments. "The information was sufficiently detailed to permit reasonable deductions about the cause of those failures and hence to decide if new technology would likely permit a new approach to succeed," he recalled, adding that:

> [T]hose documents included reports of an unguided liquid propellant ground-to-air rocket about 5 inches in diameter, called *Typhun*. Its simplicity struck me because the hypergolic liquid tanks were pressurized by a solid propellant gas generator. . . . I, among others, was asked if BuOrd wanted any of this material and/or any of these people. I chose a solid-propellant continuous extrusion press and three of the members of the *Typhun* rocket development project. I also asked that all be sent to NOTS.[69]

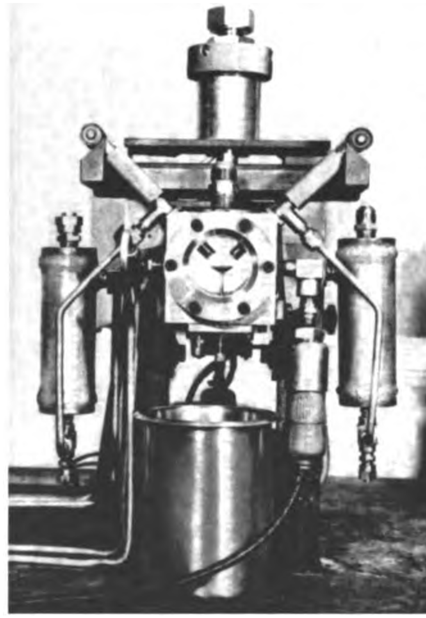
The press was soon being used at NOTS to extrude inert materials, but *Typhun* project team members were not as easily accommodated in close-knit China Lake. Influential voices raised in management meetings objected to what some felt was a pact with the devil. As a result, NOTS leaders agreed to move the three Germans to the Pasadena Annex Green Street address; from this home base they could make frequent short trips to the China Lake Pilot Plant. This compromise appeared to provide a suitably gradual introduction, and the collaboration on solid- and liquid-propellant development proved fruitful.[70]

The Navy had long avoided liquid propellants, and for good reason. Solid propellants were generally inert until they burned, but many liquid propellants were so corrosive that their shipboard storage and use were a frightening prospect. Nevertheless, liquid propellants had decided advantages if the safety problem could be overcome. They were more readily available and easier to manufacture than were solid propellants. They also had performance advantages: higher burning rates, less variation with ambient temperature, higher burnt velocity, and reduced time to target.[71]

The liquid propellant could be monopropellant, a single liquid combination of fuel and oxidizer; or bipropellant, two liquids that would mix together in the rocket. Bipropellants offered increased stability and better performance than did monopropellants and were favored in rockets with large payloads, long ranges, or powerful boosters. The Germans had already documented test results on about 6,000 bipropellant combinations. Among the more promising were the hypergolic (self-igniting) ones.

Funding setbacks kept NOTS chemists from making the rapid progress that the Germans' head start might otherwise have allowed. Work on liquid propellants initially lost out to more established solid-propellant rocket projects. Then in late 1949, the bureau asked NOTS to submit a proposal for a liquid-fueled rocket with performance similar to that HPAG, but with a markedly shorter burning time. By early 1950 Gersham R. "Gerry" Makepeace and his Liquid Propellant Branch were officially engaged in an urgent program to develop within two years a 5.0-inch liquid bipropellant rocket that could withstand a 40-foot drop onto steel or concrete without leaking or malfunctioning.[72] Before a successful firing could take place, chemists sought to better understand fundamentals of combustion phenomena, in particular the relationship between the physical and chemical processes involved in liquid-propellant combustion. Research Department chemists tried at least 95 different combinations of liquid-propellant components. Eventually a promising hypergolic bipropellant system emerged.

Unsymmetrical dimethyl hydrazine had high specific impulse; low vapor pressure; smokeless, nontoxic exhaust; and a low freezing point. When inhibited red fuming nitric acid was mixed with this fuel, nearly spontaneous ignition could be obtained.[73] With this promising propellant system and increased funding as a result of the Korean conflict, LAR development began in earnest. Makepeace assigned day-to-day responsibility for the rocket's production engineering to Tony Ozanich, an inventive rocket design engineer and fervent believer in design simplicity who became known as "the father of the LAR."[74] He and his teammates took as their first challenge the complex task of finding a way to develop and safely store a liquid-propellant rocket with the same external dimensions and burnt velocity as the 5.0-inch HPAG, but with the burn time only a quarter that of the solid-propellant HPAG. The new rocket also had to be rugged and mass-producible.


NOTS 872, Rocket Department Technical Appraisal, 1954

Ignition-delay apparatus used for measurement of hypergolic (self-igniting) liquid propellants.

Ozanich and his team decided to build on *Typhun* concepts. Since mingling the fuel and oxidizer would result in immediate combustion, keeping the two separated until the rocket was ready for use was of critical importance. But hydrazine storage brought with it a new problem. Under certain conditions, detonations in the hydrazine's vapor chamber could occur, destroying the missile's head end.

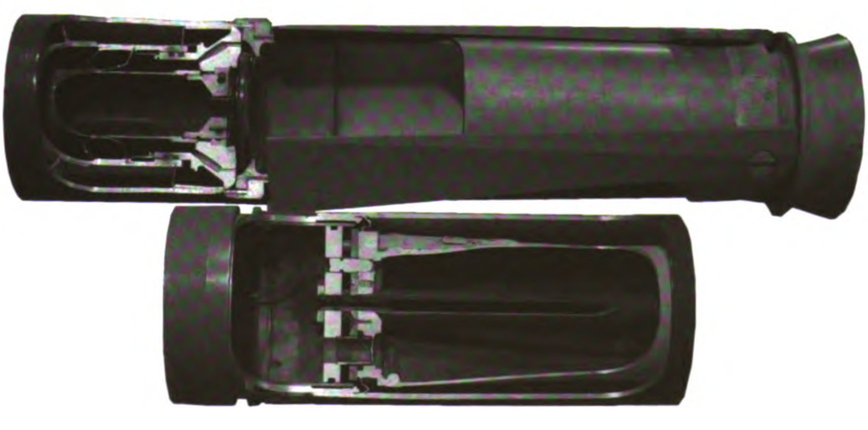
Team members also considered the corrosive nature of high-performance liquid propellants, noting that corrosion would be of little concern if they could design a rocket to withstand severe abuse without developing leaks. To keep the two propellants from premature combustion, much care went into a cutter valve that would go into action only when the rocket was fired.[75]

The station's expertise in solid propellants was also evident in a component at the heart of LAR's design—a double-ended solid-propellant gas generator that extended the full length of the liquid-propellant tanks and served to start the rocket, arm the propulsion unit and fuze, generate the pressurizing gas, and promote ignition and combustion of the liquid propellants during their entire burning period.[76]

When the first LARs were successfully flight tested in early 1952, a station report labeled the tests "a significant step forward in the technology of small liquid propellant rockets" and pointed out that the achievement of a half-second burning time in a rocket of LAR's size and total impulse represented a factor-of-10 improvement in the ratio of thrust to engine size.[77]

As the war in Korea wore on into 1952, the opportunity for the promising LAR technology to reach full development was threatened by renewed budget cuts. The American public had grown tired of the domestic sacrifices necessary to pursue a far-away battle and tedious peace negotiations. In response to real and perceived public pressure to slash defense expenditures, the Truman administration sent Congress a fiscal 1953 defense budget of $52.4 billion in new obligational authority, approximately $18 billion less than the services had asked for and $9 billion lower than the defense budget of the previous fiscal year. In turn, Congress eventually passed a budget of $46.6 billion, with most of the cuts in Army and Navy funding. The guidance came down the line: service organizations were to meet preparedness goals, but "stretch out" the period in which these goals were to be accomplished.[78]

This budget-paring process put the pressure on BuOrd to make cuts wherever possible. China Lake accepted the cut in Weapon A funding, but when LAR turned up as a candidate on the bureau's list of proposed cuts, the station



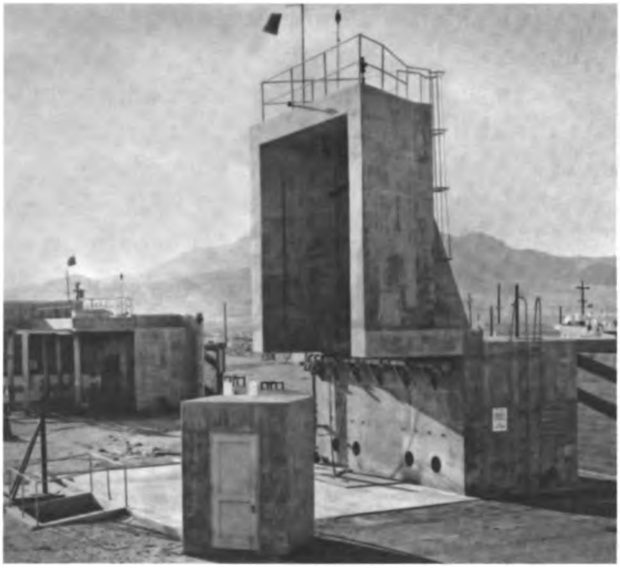
U.S. Naval Museum of Armament and Technology, photo illustration by the author

Experimental prototype for the 5.0-Inch Liquid Propellant Aircraft Rocket.

The nozzle chamber injector assembly is shown at top. Below it is the upper tank fuze housing assembly.

objected. "The bureau is apparently not aware of the state of development of liquid propellant rockets and the imminence of the successful completion of a test vehicle which is also a potential service rocket," Ellis said.[79]

As Al Gould, NOTS' consultant for rockets, pointed out, the Army's cancellation of its Loki program left the station nearly alone in liquid-fueled rocket development. "The enormous requirements for rockets and JATOs in case of another war make it absolutely essential that other propellant systems not dependent on present double base or composite solid propellants be available to help meet the overall need for propellants," he said.[80]



Facilities Review, courtesy Howard Auld

Static test facility for liquid-propellant motors.

These arguments swayed the bureau to keep LAR in the budget. Fifteen complete rounds were manufactured and tested by July 1953. Seven were launched from station ground ranges, with the remaining eight used for functional tests in the fleet to demonstrate ruggedness and reliability. Despite the advances in safety that LAR represented, however, the horror of fire at sea kept the Navy from accepting liquid propellant as an acceptable alternative to solid propellant. For that reason, the LAR development continued for only five more years. But the LAR innovations lived on, notably in systems for high-altitude missile and satellite applications.[81]

Solid Progress in Solid Propellants

Chemists, engineers, and test conductors at NOTS made the most of the station's fully equipped propulsion RDT&E facilities to generate other propellants in the lab, try them out in environmental and safety testing facilities, then move them to the pilot plant for experimental formulation and to the station's vast, remote land areas for testing. Al Camp and others in the Propellants and Explosives Department cooperated with Research Department chemists under McEwan to build on N-5's success to develop a family of plateau- and mesa-burning propellants to reduce propellant temperature sensitivities. The earliest mesa-burning propellant to reach the pilot-production phase was X-7, which was not only significantly faster than N-5 but also had higher energy and higher specific impulse than either N-5 or X-6. The new propellant, produced in limited quantities in 1953, was intended for the 5.0-inch Zuni rocket, which needed a temperature-independent propellant with a rapid burning rate.[82]

An even faster burning rate was obtained with X-8, a 1953 development for Zuni and Weapon A that the NOTS propellant team considered a milestone because it represented the first major step toward the station's goal of extending mesa- and plateau-burning propellants over the entire practical range of rocket-motor pressures, as well as over the widest possible range of burning rates. The new propellant proved that the addition of certain catalysts devised by the Chemistry Division could result in higher operating pressures without serious sacrifice of temperature insensitivity.

Another propellant developed in 1953, X-9, was formulated to serve as the gas-generating grain for the servo unit of Sidewinder. Follow-on propellants soon replaced X-9, but the application to Sidewinder proved a useful step in solid-propellant technology because it demonstrated that a slow-burning propellant with a relatively cool flame could provide performance that was reasonably temperature-independent, could emit noncorrosive gas that would not require filtering, could guarantee good shelf-life and handling properties, and could be readily and economically produced.

The X-10 propellant, a more energetic version of N-5, was developed for use in the 2.0-inch Gimlet rocket, and the mesa-burning X-11 was developed for the LAR gas generator. In 1956 X-12 demonstrated the most promising combination of catalysts yet observed at NOTS in double-base propellant burning. This new propellant had a burning rate approximately 30 percent higher than that of X-8; more remarkably, X-12's mesa region extended over a far wider pressure region. Ordnance plants prepared both moderate- and high-energy versions in quantities of 1,000 pounds or more for large-scale evaluation in several experimental rocket programs at NOTS.[83]

The value of the mesa-burning propellants came not just in the improvements they allowed in rocket performance but also in the synergistic effect they had on the solid-propellant industry. "It is this role of NOTS, to push industry by maintaining the competition for new concepts, which I think was significant," said Wiegand.[84]

Rocket-Thrown Line Charge

Developments in rocket technology also helped solve the prosaic but important task of clearing a beach of underwater obstacles and minefields during an amphibious landing. This work began in 1948 when the Underwater Ordnance Department proposed to the bureau a shallow-draft, medium-speed, remotely controlled boat that would lay a linear explosive charge through underwater obstacles and mines or project a linear charge onto a beach. Once the charge had been laid, the boat would self-destruct.

The bureau was intrigued by this proposal, but decided that the station should undertake design and development only of the forward-projected charge, which should clear a path 300 feet inland from the shoreline. The rocket towing the charge would need to be powerful enough to reel a long charge inland for that distance while the tail end of the charge remained in the boat. Tests and calculations showed that a 5.0-inch HVAR motor could accomplish the job. Getting the rocket and the line charge to function together, however, was not as easy as it sounded. "The antics of both at launch time were almost comical as each part went its own way," according to Barney Smith, who gained cognizance over the program when he became head of the Rocket Development Department's Surface Weapons Division in 1954.[85]

Initial work resulted in a metal-covered line, but in 1950, when the bureau decided that the line charge needed to be used from a manned amphibious tank (LTV) or similar craft, the possible dangers of fragmentation resulted in a fabric-covered charge. Since safety considerations dictated that the LTV needed to be 300 feet offshore when the line was projected, a 600-foot length was required for the entire line, with the explosive part to begin midway on the line. The new version, finished by summer 1951, was officially christened Demolition Line Charge NOTS Model 301A, sometimes referred to at NOTS as Hydra. The charge was formed of 1,200 bags, each filled with a pound and a half of Composition C-3 plastic explosive, strung along a nylon rope in tandem, with a fabric elastic sleeve slipped over each pair to hold them in place. A nylon sleeve, slipped over the entire length of the line and tied between each pair of explosive packages, gave the line charge a distinct resemblance to sausage links. A modified steel-tube HPAG rocket motor provided the projecting force necessary to tow the line where it needed to go. The entire apparatus—rocket with sausage links attached—was stowed in a metal launching pallet installed in the LTV's cargo compartment.

Preliminary tests in late 1951 at San Clemente Island demonstrated the practicality of the concept, and the NOTS Model 301C practice line charge,

Demolition Line Charge firing from landing vehicle onto beach, San Clemente Island.

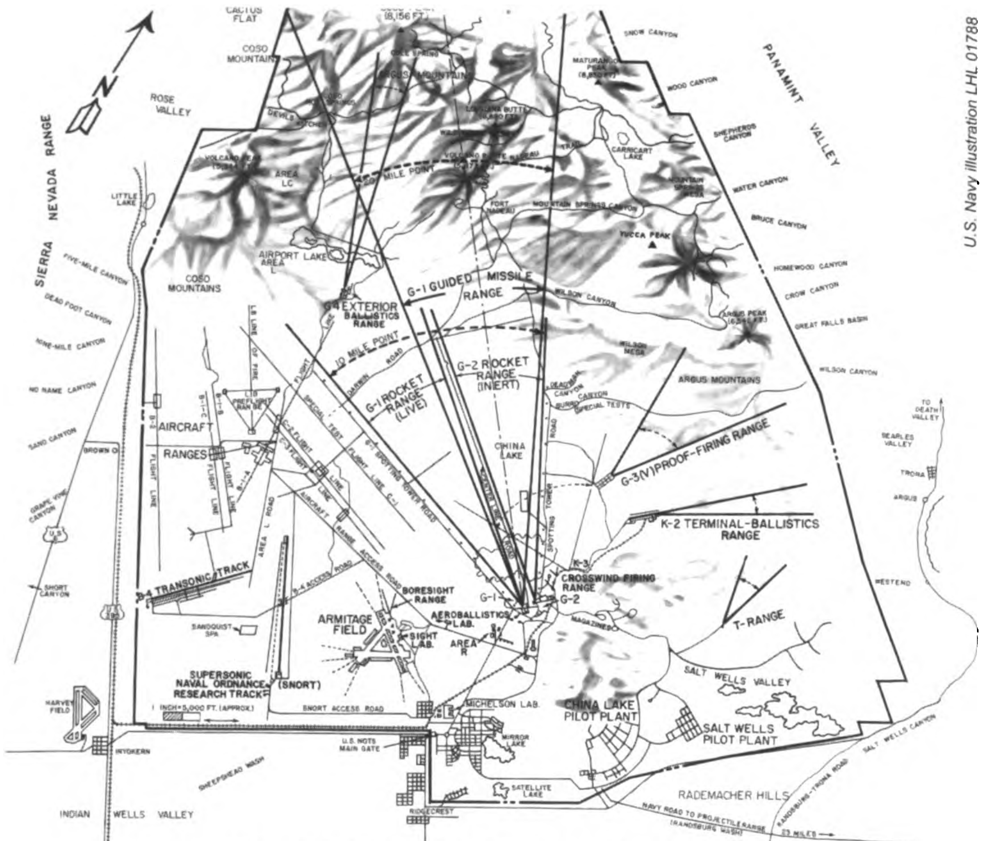
Charge assembled on landing vehicle.

TP 6413, Major Accomplishments, 1982

consisting of rubber ellipsoids bolted to a nylon rope, was developed and tested in 1952. In 1953 the Marine Corps began a series of successful vulnerability and evaluation tests. Perhaps the most spectacular of these tests was a 1954 demonstration at Vieques, Puerto Rico, where a single charge cleared every mine from a 40- by 300-foot practice field laid with antitank mines.[86]

In 1954 the charge, which BuOrd had redesignated the Projector and Charge Assembly Model 301 B, proved in a series of vulnerability tests that it was insensitive to the impact of small-caliber ammunition and shell fragments as well as to explosions of nearby antitank mines. After numerous modifications, the completed system was introduced into service use in 1962, with the technology gained through the program finding applications even today in Navy and Marine Corps scenarios of amphibious assault, close air support, and terrain clearance.[87]

The rocket line charge thus serves to demonstrate the sort of "outside-the-box" thinking that resulted in a variety of products to meet fleet needs during the post-Korean War period. Critical to those successes was the free communication between military and civilian employees and across organizational lines.



U. S. NAVAL ORDNANCE TEST STATION

CHINA LAKE ACTIVITIES

U.S. Navy illustration LHL 01788

Activities on China Lake north ranges.

U.S. 6 is now U.S. 14, and Harvey Field is now Inyokern Airport. Not shown are the Mojave B and Randsburg Wash range areas to the southeast of the main complex.

9

Indoor Flights, Outdoor Labs

While tests continued on temporary ground-firing ranges, the station modified and expanded its instrumented outdoor laboratories to meet increasingly complicated testing needs. Among testing facilities built and opened in the 1950s were Randsburg Wash Test Range, Thompson Aeroballistics Laboratory, and the Supersonic Naval Ordnance Research Track. Large-scale computing capabilities arrived and made possible a dramatic improvement in the speed and accuracy of data assessment. As the facilities expanded, so did the work, and new Navy and Marine Corps units were assigned to China Lake to help with the testing effort.

Roads, Ranges, and Data

The station's remarkable scientific and engineering advances of the 1950s depended heavily on the instrumented facilities that dotted China Lake's vast land holdings. By the early 1950s about 3,000 buildings had risen from the sand and sagebrush. More than 400 miles of hard-surface roads and 27 miles of railroad track had appeared where once only the burro tracks of prospectors could be found.[1] If a road was needed, Rod McClung recalled, range people would just call the Public Works Department and ask for the legendary Harry Potts, who would appear with a bulldozer and blade to scrape a trail through the desert. "I never knew why they flew to the moon because I think Potts could have built a road to it," McClung joked.

When bureaucratic constraints threatened to slow construction of range facilities, creative problem-solving got the job done. McClung said the Public Works officer became "quite bent out of shape" when he discovered that employees had poured a large slab to accommodate an "instrument cover." The cover, erected by range personnel over a weekend, turned out to be a full relocatable building, obligingly supplied by its maker with an instrument-cover designation and model number to allow purchase through the supply system.[2]

Creative methods also brought other assets. The first cameras used to track aerial tests were high-speed Mitchells mounted on heavy tripods attached to

Belmont "Bel" Frisbee operating a 40-mm gun turret converted to photographic use.

Operators found the turret, NOTS' first tracking camera mount, cumbersome to transport and operate.

M-45 mobile tracking mount, 1958.

U.S. Navy photos LO 43904 (left) and NP/45 LO 14883, courtesy George Silberberg

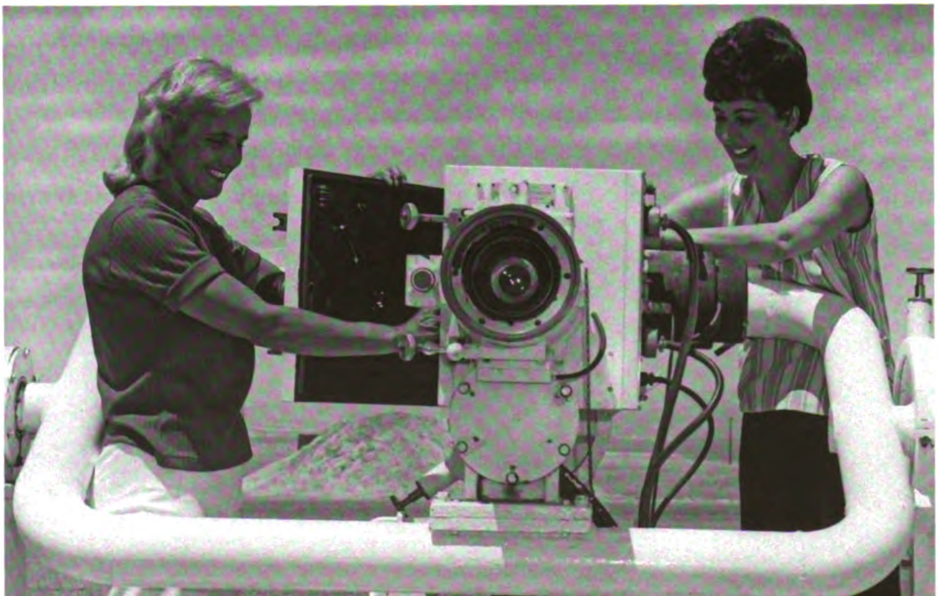
substantial posts about four feet high. The need for more accurate tracking dictated a faster tracking rate and longer focal lengths than the 17- and 20-inch lengths then in use. George Silberberg, an inventive member of the Metric Photography Branch, AO&T Department, obtained two M-45 .50-caliber machine-gun mounts from Commander Chick Hayward and directed modifications in the NOTS shops to come up with the "Gooney-bird" tracking camera, a highly satisfactory solution that increased the maximum possible tracking rate by at least 20 degrees a second. The Gooney-bird, a self-contained unit mounted on a trailer and towed by a truck containing a diesel generator, could also be repositioned to suit specific test requirements. Although the cameras used—Mitchells and high-speed Eastmans—were standard issue, Silberberg's timing adapter, azimuth and elevation synchro data box, lens adaptor, and synchronous motor were innovations that made the system a workhorse of the station's metric photographers.[3]

Range people also thought "outside the box" when it came to employees. From the first, women with technical training and ability found positions of responsibility at NOTS. Others found professional niches by learning on the job. By demonstrating her proactivity as a secretary, Marie McArtor earned the opportunity to operate tracking cameras. She became the first female missile tracker in the United States in February 1952; Estaline "Essie" Cottingham became the second a few months later.[4]

To go with the specialized instrumentation and trained people, NOTS also acquired some spectacular targets when masses of B-29 Superfortresses literally landed in China Lake's backyard after the close of the Korean War. Some flew in directly from overseas assignments, others came from Davis-Monthan Air Force Base, Arizona. Some were disassembled, trucked to China Lake piecemeal, and reassembled; others were towed to the desert.[5] The B-29s came from the Air Force, which saved thousands of dollars per aircraft in mothballing expenses by sending them to NOTS.

China Lake test conductors welcomed the highly visible aircraft, which could be used as targets for long-range or high-altitude warhead and fuze tests. And the B-29 was as tough as it was massive.

"This was during the heyday of warhead design, and we needed the toughest aircraft structure we could find," said C. John Di Pol, a 1950 arrival who began his career as a test-facility designer, soon became an instrument designer, then moved up through the management ranks, ending his career as head of the Range Department.[6]



U.S. Navy photo by Philip H. Beard, PH2, courtesy Marie McArtor

Missile trackers Estaline Cottingham (left) and Marie McArtor with a Bowen high-speed camera.

C. John Di Pol.

Memories differ about who first took steps to obtain the surplus Superfortresses for NOTS. Bill Leonard, remembered by his peers as a world-class scrounger, apparently had a key role in the transfer. When Newt Ward heard that the B-29s were available, he agreed that AOD could use a few. Once the aircraft started arriving, Newt's brother William C. "Bill" Ward recalled, "They kept coming in from everywhere, and nobody could turn off the pipeline."[7] Despite administrative warnings that the B-29s and their components "are not considered surplus and unauthorized removal of property from the airplanes is a serious offense," large Plexiglas bombardier bubbles made regular appearances as punch bowls for Michelson Lab Christmas parties. Other B-29 parts were squirreled away in garages and back lots.[8] By the time delivery of surplus B-29s to China Lake stopped in late 1956, between 70 and 100 birds had arrived. The Research Board decided that "enough aircraft for a 5–10 year supply for fuze and warhead studies" was enough. For nearly half a century thereafter, the Superforts and their parts—notably double rows of wings set up as high-altitude bombing targets—served as targets for many types of tests.[9]

By grabbing assets wherever they could, NOTS employees were able to conduct sophisticated tests even on the ranges of the early 1950s, which still

Public Works trucks towing B-29 aircraft to Randsburg Wash Test Range, 2 October 1953.

G-1 Range launching area.

had a makeshift air about them. The biggest and most active ground ranges were G-1 and G-2, managed by the Test Department, successor in 1950 to AO&T. The huge G-Range complex was used for numerous ground-to-air, air-to-ground, and air-to-air weapon tests, especially those where the targets were remotely controlled pilotless aircraft.

All exterior-ballistic rocket tests involving high-explosive warheads were conducted on G-1 Range, which had been laid out in 1944. The line of fire began at a huge launching pad on the China Lake playa and extended 37 miles across the rugged Coso Range to the northern boundary of NOTS. The range was highly instrumented, with three tracking radars and fixed and mobile tracking cameras. One of the first areas used by Caltech after the establishment of NOTS, G-2 Range ran parallel to G-1 for a distance of 20,000 yards. G-2's flat terrain made for easy recovery of the inert rounds fired in exterior-ballistics tests. The range was also used for launcher development.

The presence of State Highway 190 from Lone Pine to Death Valley and of the small mining town of Darwin, both only two miles north of the boundary, meant that only short- and medium-range missiles could be fired from G Range. Even with these limitations, however, the range afforded the most completely instrumented facilities in the country for testing missile boost and separation phases. Investment in G-1 and G-2 during the first few years of the station's existence was substantial; one 1951 study showed $7.2 million spent and projected for improvements.[10]

In addition to G-1 and G-2, air-to-ground ranges included the B-1 and C-1 fixed-target ranges, the LB-1 bombing range, and the B-4 moving-target range. The difference between B-1 and C-1 was that B-1 was instrumented for flight conditions out to 15,000 yards slant range and up to 40,000 feet altitude. LB Range, with its adjacent landing strip, was equipped for evaluation of aircraft rocket launchers and guns mounted in or on aircraft and aircraft structures. Central to the operation of B-4 was a railroad track on which tests of rockets and missiles were carried out. The first range constructed at NOTS, C Range, usually called Charlie Range, was valuable for fleet training purposes. Pilots took advantage of instantaneous feedback on dive angles, release altitudes, slant ranges, and impact points. The Charlie Range crews were on duty day and night, seven days a week, helping convert Navy fighter groups that had been trained for air-to-air gunfighting and ground strafing to attack groups that dropped bombs and fired rockets.

The Coso Military Target Range, covering about 70 square miles of mountainous terrain in the northwest corner of the China Lake Complex, offered partly hidden or camouflaged targets simulating conditions pilots might encounter in mountainous terrain. Pioneering range engineer Duane Mack planned the range and, with the help of Anthony "Tony" Bachinski and others, equipped it with war-surplus tanks, two-by-fours laid out to emulate railroad tracks, a bridge constructed of surplus Bailey bridge units, and other makeshift but convincing-looking targets.[11] Mack also led the effort to plan and coordinate Charlie Range. Under his leadership, range coordinators become renowned among fleet squadrons for their can-do spirit."[12]

McLean later praised NOTS ranges for their innovative instrumentation, which "led the way in techniques for measuring the accuracy of fire-control systems in airplanes ever since." Among the ranges using China Lake ranges as models were those at El Centro, California; Yuma, Arizona; Cherry Point, North Carolina; Pensacola, Florida; and the island of Puerto Rico. [13]

Courtesy Maturango Museum

Range Engineer Duane Mack in the Charlie Range control tower.

Great strides also occurred in the rapidity and accuracy with which data could be assessed. In the early days at NOTS, telemetry film assessment required detail-minded employees who sat for hour after hour, peering at test-film footage through microscopes, laboriously counting pulses, and painstakingly writing these measurements down. Workers complained of tedium and ruined eyesight. One of the starers and counters was Lee E. Lakin, a graduate of the University of Chicago, who arrived at NOTS in 1946. During his first years on the desert Lakin could scarcely have envisioned the high-speed empire over which he would preside as head of the Computer Sciences Division in 1960–1981.[14] The mechanical calculators available to help in data assessment could perform only the most rudimentary functions. But as Lakin and his peers bent over their microscopes, the computer revolution had already quietly begun. In 1946 the world's first fully electronic computer, the Electronic Numerical Integrator and Calculator (ENIAC), invented by Dr. J. Presper Eckert and Dr. John Mauchly, had begun operation at the University of Pennsylvania.


Courtesy Arlee Lakin

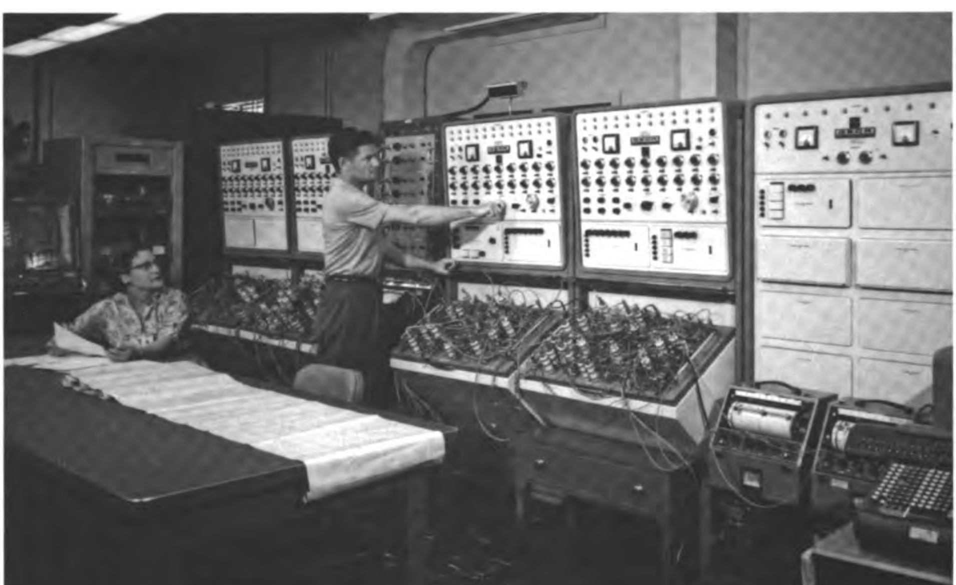
Lee E. Lakin in 1948.

In response to the promise of the computers that followed that pioneering development, the Research Board coordinated a "high speed computing survey" in May 1948 to determine the extent of NOTS' computing and calculating requirements.[15] The technical workforce responded positively, but somewhat uncertainly. To capitalize on the revolution in work methods that computers represented, the station needed a computer champion, someone who understood these new tools and who could supervise installation and training. That champion soon emerged in Harley E. Tillitt, who had reported to NOTS in 1946, working at the Pasadena Annex for a year before transferring to the desert. A lanky iconoclast with unusual skill in communicating technical concepts, Tillitt became head of the new Computing Branch of the Research Department's Mathematics Division in late spring 1949.

That July, when AO&T wanted to buy an analog computer, Warner convinced the Research Board that overhead funds should pay for half of the $31,156 cost. In return, the computer would be made available to other departments "a reasonable part of the time." In the interest of widespread participation in planning for long-term computer needs, the board asked Tillitt to conduct a survey and submit a plan to fill the needs his survey identified.[16]

As the planning went forward, a homemade analog computer began operating in Bill McEwan's laboratory. This harbinger of efficiencies to come was designed and constructed in early 1950 by McEwan and Sol Skolnik, both supervisory chemists in the Chemistry Division of the Research Department. The computer, made of old radar and radio parts, dramatically reduced the time necessary to calculate the theoretical performance characteristics of certain propellant compositions. Although McEwan's previous calculation methods had been refined to an easily understood routine, an operator using a desk calculator could hope at best to solve a problem a day. The computer could solve the same problem in about 20 minutes—an impressive time savings, since scientists had to solve least a dozen problems before they could predict the performance of a new propellant composition.[17]

Data collection on the ranges also improved with new automated tools such as a telereader, which consisted of an electronic data recorder and a reader that punched the data out on IBM cards, and which for the first time allowed real-time automatic recording of data during airborne and ground tests.[18]



Courtesy U.S. Naval Museum of Armament and Technology

Goodyear Aircraft Corporation Electronic Differential Analyzer (GEDA).

The analog GEDA, first manufactured in 1948 and introduced at NOTS in the early 1950s, solved 12th-order differential equations at about 500 times the rate of slide-rule methods.

Efforts To Coordinate Ranges

Until the early 1950s each major military range had its own frequency assignments, type of funding, and instrumentation standards. The T&E community realized that a unified position could help the services combat congressional criticism that range facilities were wastefully duplicative.[19] In June 1950 the Defense Department assigned each military service the responsibility for operating one national missile test range: the Army for White Sands Proving Ground in New Mexico; the Navy for the Naval Air Missile Test Center, Point Mugu; and the Air Force for the Long Range Proving Ground, Banana River, Florida.[20] The three ranges formed a Range Commanders Conference (soon renamed the Range Commanders Council, or RCC) in August 1951 "to provide informal contact and exchange of information of mutual interest among the commanders of ranges engaged in guided-missile testing."[21]

The commanders realized that many of the problems brought to the RCC were best understood and resolved at the working level. They also hoped a unified expression of need would result in DoD funding for necessary instrumentation improvements. As a result, the Inter-Range Instrumentation Group (IRIG) and several specialized working groups were established in March 1952.[22] The groups met frequently thereafter to work on joint procurement, telemetering standardization, and frequency assignments.

The Naval Ordnance Missile Test Facility, White Sands, and NOTS joined the RCC in December 1954 when the station hosted the newly expanded group. Much of the discussion focused on the advantages and disadvantages of the modified industrial funding system under which the station charged its range customers. In contrast, the national ranges received funding from appropriations so that services to range users were free. Under the China Lake system, all users paid fees that covered the costs, including overhead. As a result, projects coming in from outside frequently complained about the fees. Meeting attendees agreed that all ranges should be funded on a common basis, but the suggestion that all participating ranges adopt the NOTS system was not popular.[23]

The funding issue arose again repeatedly over the years, with the station holding fast to the position that its modified industrial funding system, which charged customers for both overhead and direct costs, was a more responsible way to track costs than other systems in use.[24] "NOTS testing used to cost much more than Mugu, Edwards, or White Sands because there the customer just paid for the film and the overtime, but here he was expected to pay for the whole project," Bud Sewell explained. "Still, it really amounted to a saving of money for the government in the long run. The funding was much more realistic, and you got more services than just tests."[25]

Getting Terrier Ready for the Fleet

Although from the perspective of NOTS mavericks, the ranges existed primarily to serve the development work going on in the laboratories and shops of China Lake, programs developed elsewhere sometimes took first priority on the station's ranges when higher authority established urgent requirements. Terrier, a descendent of the STV-3 version of Bumblebee, was the product of continued efforts to develop a shipboard antiaircraft weapon. Requirements for the new version, however, were considerably more complex than those for the original Bumblebee, with its relatively simple test vehicles. In contrast to the earlier emphasis on control systems and other missile components, the focus of the Terrier program at NOTS shifted to tests of overall missile performance and evaluations of subsystems.[26] Terrier funding was paying for an expansion of missile-test facilities, including data-assessment facilities. But the urgency of the program meant that some of the most expensive Terrier installations were made on the temporary G-1 Range where test conductors were operating until the permanent ranges could be completed.[27]

Flight tests of Lot 0 Terrier (STV-3B) began on 16 February 1950, with the firing of the first of a series of prototype missiles against F6F drone targets. So demanding were the Terrier tests that other programs had difficulty fitting in. Peter Nicol and John Kleine, both early-timers at NOTS, staffed the Test Department's Test Scheduling Office. Nicol recalled the uproar in the scheduling meeting when he announced he had scheduled a Terrier and a Meteor to fly on consecutive days, a schedule that would mean moving a lot of range instrumentation around after hours, plus long hours for the test personnel. According to Nicol, Edward R. "Ted" Toporeck, head of the Test Department, "stood up and said, 'I think we can do it. . . . I want you fellows to figure out how we do it." And we left it on the schedule, and they did it." Such arguments occurred at every Monday's scheduling meeting.[28]

Fully as important as the range space for Terrier tests were the men to support them. In January 1950 the Marine Corps Guided Missile Training Unit, 50 men strong, came to NOTS to evaluate the Terrier missiles for Marine Corps use. The battalion was assigned space in Stran Steel Building No. 2, a World War II-era structure scarcely more weathertight than a tent. The unit, the first mobile organization established by the Marine Corps in support of its surface-to-air missiles, became the First Provisional Marine Guided Missile

Battalion in October 1951 and was officially assigned to work with the Test Department.[29]

After the start of the Korean conflict, the Navy decided to put Terrier on board ship despite the deficiencies the missile still demonstrated. Cruisers *Boston* (CAG-1) and *Canberra* (CAG-2) were withdrawn for conversion and measured to establish space constraints Terrier would have to be designed to meet. The station began testing Lot 1 missiles, the first Terriers manufactured to product specifications, in October 1950. By August 1951, NOTS had fired a baker's dozen of the Lot 1 Terriers, including three with live warheads. Tests of Lots 2 and 3 followed later that year, and the first of the Lot 4 (production) Terriers flew over the China Lake ranges in late 1951.

Encouraged, BuOrd authorities decided that reliability had been proved and that Terrier could be manufactured and assembled in quantity. Bureau officials believed that the transition from development to production could be accomplished with only minor problems and furthermore that production decisions could be turned over to the contractor with a minimal involvement from then on by the development agency. Both of these assumptions turned out to be wrong.

In mid-1951 Terrier's prime contractor, the Consolidated Vultee Aircraft Corporation (CVAC, also known as Convair) began manufacturing and assembling Terrier Lot 4 missiles. Development and quality-control problems soon became apparent. An alarmed BuOrd decided to bring the development staff of Johns Hopkins' Applied Physics Laboratory (APL) back into the program as a major participant. Late that year Terrier became America's first production missile to reach the evaluation phase, and the bureau assigned the station the responsibility of evaluating pre-production and production Terriers to determine their readiness for tactical testing. In hopes of improving communication among the organizations working on the missile, BuOrd set up a Terrier Task Group, with representation from the bureau, APL, Convair, and NOTS.[30]

By January 1952 NOTS had flight-tested 13 vehicles incorporating Terrier's preliminary design and had demonstrated that a Terrier could be launched from a zero-length launcher into a moving radar beam and then ride the beam to its destination. Reliable operational procedures for drone control and for firing coordination were also established.[31]

The renewed involvement of APL in Terrier development brought a flurry of changes, with the immediate result that, as BuOrd Chief Schoeffel said, "Things just weren't getting done." In fall 1952 K. T. Keller visited the Terrier production facilities. He returned to insist that Schoeffel could solve the missile's production problems only by establishing one clear leader. Schoeffel selected Commander Francis E. Boyle, a submariner on assignment in Re9, to look into the problems at the Convair plant. With help from a small group representing Ma9 (the bureau's Manufacturing Branch), APL, Vitro Corporation, NOTS (represented by Ted Toporeck), and Convair itself, Boyle began seeking a way to get the program back on track.[32] Boyle's group concentrated on planning the development and production phases of the program and in a few months "managed to get things fairly well straightened out," according to Schoeffel. He directed that the Terrier production contract be amended to require Convair to guarantee that the missiles would work when they were checked on their launchers. This new clause in the contract had the positive effect, Schoeffel recalled, that "everybody turned to and started working like hell."[33]

That December Hack Wilson, then associate head of the Test Department, reviewed Terrier's problems for the Research Board and presented the "major object lessons to be drawn from these experiences":

> a. Engineering changes introduced in production often result in significant production problems.
>
> b. Participation by the development organization is necessary during the engineering change phase if expensive and extensive delays are to be minimized.
>
> c. The application of technically directed quality control practices is necessary to insure the production of acceptable weapons and weapon components.[34]

Wilson's "lessons learned" meshed well with a list of problems presented by Re9b in a meeting of BuOrd's Research and Development Planning Council the following month: "(a) lack of experienced contractor; (b) reluctance to call on outside help; (c) underestimation of time; (d) lack of duplicate effort in certain areas; (e) lack of coordinated missile designs; (f) basic design proven but producibility not proven." A representative of Re9a also commented that "the handling of this program is an example of several organizations covering the same ground in a developmental program without using the experience of organizations which had previously worked in the field."[35]

NOTS was also learning these lessons with Mighty Mouse and the Antisubmarine Rocket (ASROC). In later years, the station would apply the same valuable lessons many times as it worked with contractors and served as a troubleshooting organization for programs developed elsewhere. The lessons had also been taken to heart at Convair, where company officials were eager to show that they could make good on their guarantee. On 30

January 1953, Convair officials accompanied Schoeffel and Boyle to G Range to see the improved Terrier in its 13th test (an apt number, as it turned out). So meaningful was the demonstration to Convair that the president of the company, retired Air Force General Joseph T. McNarney, former commanding general of the Air Materiel Command, was also there, along with a phalanx of company officials.[36] One task assigned to the experimental officer and his staff was the duty of escorting important visitors, and Lieutenant (later Captain) Walter M. Schirra, Jr., subsequently one of the nation's first seven astronauts, and his buddy, Lieutenant Commander William T. "Tom" Amen, had drawn the duty for the Terrier test.[37]

Once Schoeffel, McNarney, and the other visitors were settled on bleachers overlooking the flight line, all eyes turned skyward toward a drone. The Terrier began its flight well, but suddenly veered straight up and went into a hammerhead stall, an inadvertent flip that sent the missile hurtling down toward its watchers. Schirra remembered that as the visiting dignitaries began "ducking under what little protection there was," the two NOTS pilots stared up open-mouthed, uncomfortably aware that the missile "would hit nearby and possibly in our midst."[38]

After the incoming Terrier landed harmlessly on the desert about 200 yards from the reviewing stand, the high-ranking observers regained their seats, sharing relieved laughter with their escorts, who, according to Schoeffel, attributed the failure to the likelihood that "You two old buzzards up there in the first-base bleachers scared the devil out of it!"

The visitors ended the day with dinner and dancing at the Officers Club, where P. D. Stroop's charming young daughter convinced McNarney to take a turn around the dance floor. "He probably hadn't danced in 50 years, but she got him out there and had him hopping around in great style," Schoeffel said.[39]


U.S. Air Force photo

Lieutenant Walter M. Schirra, Jr.
Schirra, who served exchange duty in Korea with the Fifth Air Force's 136th Bomber Wing, is shown in his Air Force F-84 Thunderjet after participating in one of the war's biggest aerial battles.

Terrier tests continued in a less exciting manner, and the missile became operational in 1956. As for Schirra and Amen, the two established a place of honor in their repertoire for a tale they dubbed "The Admiral Seeker."[40]

Railroads for Rockets

An increasingly popular way to learn how a system or component would function under operational conditions and yet keep testing costs in line was to subject the item to an instrumented, relatively inexpensive track ride. Test tracks could bridge the gap between free-flight launches and static tests in the laboratory, allowing study of the effects of acceleration and wind on a test item's control surfaces. The station had scarcely installed its main gate when it began preparing for this work, with its earliest track (two rails 1,500 feet in length) opening for business in 1945 on K-2 Range. The track at K-2 was used for exterior-ballistics tests of early spinner rockets as well as for tests of warhead and fuze impact at free-flight speeds. The targets were usually heavyweight steel plates, and the "carriage" bearing the test warhead or fuze was often the rocket itself, which flew down the track on shoes anchoring the rocket to the track. At the muzzle end of the track, explosive bolts blew the shoes off the rocket motor, leaving the test item to fly into the target, located only a few yards away.[41]

On the heavily used B-4 Track, constructed in 1946, a rectangular framework supported by four rail slippers moved down a 2.76-mile standard-gauge two-rail track at speeds of up to 605 miles an hour. Two HVAR motors accelerated the target carriage, with a reversed HVAR motor stopping the carriage at the end of the track.[42] A third rail was laid downtrack between the two main rails for a 7,000-foot distance starting 4,000 feet from the breech.

U.S. Navy photo NP/45 57028

Sled preparations for rocket-launcher test on B-4 Track.

Lark ramp with G Ranges and the Sierra Nevada in the background, March 1953.

The track was carefully aligned for the first 4,500 feet, but the rest of it was no more precise than an ordinary railroad. Although B-4 Track was not long or precise enough to suit many range people and their customers, it was useful for early Sidewinder tests and for other simulations where a smooth ride was unnecessary. Some of the lighter test vehicles attained accelerations as high as 120 *g* and velocities of up to 1,980 feet per second.[43]

The 450-foot-long Lark ramp was frequently used in early tests but was not long enough to allow adequate time for the rocket to emerge from a conventional launcher. Special motors of short burning time and high thrust were necessary to boost the carriage speed. The test rocket was clamped into a position forward and above the booster carriage by an explosive bolt. When the carriage neared the end of the rail, the rocket and the bolt ignited simultaneously. The bolt then released the motor into free flight at supersonic speed.[44] In 1951 a 550-foot six-degree ramp replaced the Lark ramp to test missiles under simulated aircraft-launch conditions.

Another track, K-3, was a modified section of the standard-gauge railroad track laid between Inyokern and the Terminal Ballistics Range (K-2) in the early days of NOTS. The track had two purposes—to deliver munitions to a transfer dock for truck transport to the main magazine area located northeast of B Mountain and to deliver heavy steel target plates to K-2 Range. In 1953 the station improved a 2.8-mile section of the track by superelevating some of the curves and inspecting and aligning all the rail joints, then simulated shipboard firing conditions for crosswind firing tests of Weapon A.

U.S. Navy photo NP/45 05723

Buick-powered prime mover towing rocket launcher on K-3 Track, April 1953.

These modifications allowed the Test Department to run a prime mover that incorporated a Buick automobile engine (the most powerful of its day) and automatic transmission down the track at speeds of up to 60 knots. The prime move pulled a flatbed trailer carrying the test item and its launcher. Red warning lights flashing, horn blaring, the streamlined prime mover accelerated and intercepting devices placed along the track triggered launch, at which point the rocket launcher the locomotive had in tow would begin firing rockets at various crosswind angles.[45]

Testing needs of NOTS rocket programs soon required a longer track, and in December 1954 G-4 Track opened for exterior and terminal ballistics tests on the edge of a ridge overlooking Airport Dry Lake. The 3,000-foot-long track was designed to accommodate heavy transverse loads and firings of high-velocity long-burning rounds. A 200-foot drop-off beyond the track muzzle permitted measurement of high-speed events in the airspace just beyond the track muzzle.[46]

Despite the variety of tracks and the specialized instrumentation NOTS technical people designed for those tracks, work sometimes had to be turned away because the tracks were not long enough. The rapid evolution of aircraft and rocket designs resulted in test parameters that frequently included a requirement to push through the sonic barrier and beyond. High speeds could be simulated in wind tunnels, but a choking effect often spoiled attempts to simulate flight conditions through the transonic range (600–800 miles per hour). Both the Air Force and the National Advisory Committee for Aeronautics (NACA, forerunner of NASA) were working on new supersonic tunnels that incorporated design modifications to avoid this phenomenon, but most supersonic test facilities did not begin operation until the mid-1950s.[47]

Even as NOTS installed and improved its tracks, the station and other installations with test ranges were scrambling to develop tracks that could tolerate higher speeds. In November 1947, after having studied various track lengths and configurations (even a circular track), NOTS sent BuOrd a plan for an aptly named Long Track stretching as far as 25 miles into the desert. In February 1948 the bureau authorized the station to begin a feasibility study for a more affordable high-speed three-rail track 11 miles in length.[48]

Long Track plans encountered their first major snag that September when the Research and Development Board turned down the bureau's request to begin construction. The RDB wanted to buy the time to investigate which of several track proposals to endorse. An Ad Hoc Group on Track-Type Testing Facilities, chaired by John K. Northrop, president of Northrop Aircraft, Inc. and designer of two pioneering tracks for Edwards Air Force Base, began surveying existing and planned tracks.[49]

As the RDB awaited the Northrop study findings, BuOrd added a $1-million line item to the fiscal 1950 supplemental appropriations bill as the first payment on an estimated $5.5-million total cost for the proposed track. With that encouraging news, NOTS selected the site—a flat rangeland a mile and a half north of Inyokern Road and approximately midway between the China Lake administrative area and the village of Inyokern. In April 1949 BuOrd approved the proposed facility's name: Supersonic Naval Ordnance Research Track (SNORT).[50] The Research Board established task groups, following Thompson's suggestion that AO&T plan and acquire the track's instrumentation and test carriages and that UOD design the track and its facilities.

Pasadena personnel, in particular James H. Jennison, head of UOD's Development Engineering Division, had directly applicable experience. The introspective Jennison had designed the most important facilities at Morris Dam and had been a bridge designer for the State of California prior to joining NOTS Pasadena in 1943 as a Caltech employee. He had a passionate lifelong interest in welded-bridge design.[51] Equally qualified and just as obsessed with his design tasks was Carl H. Heilbron, who was reassigned from AO&T to UOD so he could work more closely with Jennison.[52] The two men studied many track and rail configurations, rejecting the more unconventional ones in favor of three identical rails laid on a foundation.[53]

In December Thompson authorized Local Project 583, "Exploratory Studies for Project SNORT," thus putting the planned track in direct competition for

E&F funding with Sidewinder and other projects more obviously fitting the intent of discretionary funding ordinarily reserved for research endeavors.

"The SNORT Track was sold by L.T.E. Thompson to be another type of aerodynamic research tool, a sort of wind tunnel," said Highberg, then head of the Exterior Ballistics Branch. "We in the Ballistics Division said it would never be used for that purpose and were trying to get a replacement for the 1,500-foot track on K Range." Thompson got Highberg's support for SNORT by agreeing to support the idea of constructing the proposed 3,000-foot G-4 terminal-ballistics track.[54]

In-house support for SNORT was thus ensured, but a roadblock soon loomed at the national level, an early result of an August 1949 amendment to the National Security Act of 1947 that gave Defense Secretary Johnson additional administrative authority over the three services.[55] Johnson, who had sold the amendment as a way to save money, was eager to demonstrate results. He selected General McNarney to chair a National Defense Management Committee charged with locating areas where savings could be made.

Until the Korean conflict took the political heat off military cost cutting, McNarney appeared well on his way to reducing the defense budget by the amount Johnson had predicted.[56] The search for savings led McNarney to request on 15 June 1950 that all construction funds for SNORT be held up until the RDB had a chance to determine that the best available track-design information had been used. In an ironic coincidence, just two days later the 81st Congress passed Public Law 564, authorizing SNORT's eagerly awaited $5.5-million funding.

McNarney's roadblock was soon removed, however. Swayed by a positive report from the Northrop group, he released SNORT funding after the station showed that the design of the track incorporated "the best experience obtained from the operation of existing tracks."[57] The station was already studying the 2,000-foot and 10,000-foot tracks at Edwards Air Force Base and had conducted several tests on the 10,000-foot Muroc track.[58] On 26 October the 81st Congress passed Public Law 759, appropriating $950,000 to cover SNORT's initial study and contracts. In November, as promised, McNarney released his restriction on the track's funding.[59] The last impediment to construction seemed to have been removed.

SNORT Construction and Use

Jennison became chief engineer of the SNORT project in August 1950, and by mid-December his 20-man design group in Pasadena sent the track's first schematic drawings to the bureau. The plan was for two rails at standard railway gauge for the full 11 miles, with a third rail extending partway to provide a narrower gauge.[60]

By the end of spring 1951 NOTS had conducted eight sled runs at Edwards and 31 runs on B-4 Track. That July Jennison accepted a challenging new job as head of the station's Design and Production Department, but continued the track project too. The entire SNORT design staff transferred into D&P with him.[61] Then in October Congress appropriated $4.55 million, the final installment in the $5.5 million the station had estimated the track would cost. On 24 October Commander S. K. Wilson, the station's Public Works officer, began advertising two contracts, one for the track headquarters area and the other for the first 4.84 miles of the track itself. When Jennison, Heilbron, and others in the SNORT planning group opened the bids in late November, they were shocked to discover that the lowest bid for the first two increments was for more money than was available for the entire project.

Associate Director for Engineering Saylor called an urgent meeting in his office. Jennison and his staff recommended scaling back to 4.47 miles of track, a plan that the D&P staff believed would give "the barest minimum in track facilities . . . the best that can be had under the circumstances." The Research Board agreed and urged Commander Wilson "to proceed with construction of the track immediately, before prices go any higher."[62] The grand plans for the Long Track were then scaled back to a track only 4.1 miles long with just two standard-gauge rails for its entire length. But even this truncated version would be the longest precision two-rail track in the country.

Construction of SNORT began on 14 January 1952, as the contractor, J. A. McNeil Corporation, scraped off a long north-south gash in the desert, bearing slightly to the west to avoid interference with G-4 Range, also under construction. Workmen poured two hefty reinforced-concrete beams running

U.S. Navy photo NP/45 29145

Sidewinder streaking down SNORT in an early sled test.

under SNORT's entire length with a horizontal slab joining the two beams. In cross-section the joined beams and slab formed an H-shaped structure resistant to both horizontal and vertical stresses. This entire structure was buried in a compacted earthwork base. The standard heavy crane rail selected for SNORT was laid in 50-foot lengths to minimize the number of joints. The rails were carefully set to withstand a blistering 250 degrees. The new track incorporated provisions for water brakes and sand brakes, with retro-rockets to be added for tests that required large controlled decelerations.[63] As track construction made rapid progress, SNORT's designers concentrated on test-sled design, which they considered fully as important as that of the track itself.

To the relief of the test conductors, minimum test operations that began with a "TIM Go-Devil, 800 f.p.s." sled run on 18 November 1953, showed by early February 1954 that test vehicles could operate at the hoped-for speeds and that the water brake would stop the vehicles as planned.[64] A test series of the Falcon fuze, run during the last half of the month, was the first single-rail use of the new track. Like all of the station's range assets, SNORT would be used many times to support the programs of all the military services; ironically, this first non-Navy use was for the trouble-plagued Falcon missile, the Air Force choice in preference to Sidewinder.


U.S. Navy photo NP/45 LO 20603

Test preparations at SNORT, July 1956.

With all instrumentation operating as designed, SNORT was ready for its grand opening. In late March 1954 nearly 1,300 community members lined up to watch the track's first public demonstration, the main event in a celebration of the Test Department's fourth birthday. Lending a festive air was a handicap event in which the visitors guessed the total distance three rockets fired on the track would travel.[65] The demonstration proved so popular that Armed Forces Day celebrations for many years included SNORT demonstrations as impressive, reliable, relatively inexpensive symbols of China Lake test activities.

More to the point for the testing community, NOTS at last had a high-speed track that filled the gap between static testing of wind-tunnel models and free-flight testing of full-scale rockets and missiles. The track is still in use, with SNORT's versatility accommodating runs of low or high speeds and short or long durations. Customers from the commercial sector use the track, as do the military services, contractors, and foreign governments. Projects using SNORT over the years have ranged from aircrew ejection systems for aircraft and spacecraft to live ordnance components to movie special effects.

Indoor Range at Thompson Lab

Even as SNORT test operations began, another specialized facility for high-speed measurements was already on its way to oblivion after only a year of operation. Thompson Laboratory, an instrumented indoor aeroballistics range, was billed as "one of the very few installations of its kind for conducting aerodynamic research and development with scale models of rockets and missiles."[66] Planning for Thompson Laboratory began in 1945, with a Ballistics Division design of an instrumented indoor range for collection of ballistic and aerodynamic information on gun-launched missiles in free flight. For the first five years Dr. Arthur L. Bennett, head of the Ballistics Division, led the project.

Construction started in February 1950, about the time Highberg took over project direction. Working on the building's design ever since he became head of the Ballistics Division's Exterior Ballistics Branch in 1948, he was fascinated by the task, but frustrated by a $585,000 funding limitation.[67] The facility was completed in 1953 at a cost of about $1.2 million, a bargain even in those days, considering the amount of instrumentation required. Costs stayed low because the station developed much of the instrumentation.[68]

A projectile under test (a small missile up to 5 inches in diameter or a model of a larger one) was fired from a gun barrel at one end of the building. During the model's flight through the 480-foot length of the indoor range at a velocity of up to 6,000 feet per second, every inch of that passage was documented by paired cameras spaced at 20-foot intervals. By the end of the flight, as the item crashed into a missile stop outside the other end of the building, researchers had as many as 220 pairs of photographic images to analyze.

U.S. Navy photo NP/45-59411, courtesy Maturango Museum, Wallace Allan estate

Loading a 3-inch gun to fire down the length of the new aeroballistics laboratory, 1 June 1953.

Limited funds permitted equipping only 11 of the planned 23 photographic stations, but the range still provided the most complete photographic coverage yet available in a U.S. free-flight enclosed range. As the model flew by, each pair of cameras took a series of simultaneous pictures, "chopped" by microflash illumination, with each photographic plate bearing up to six sharply defined silhouette images of the item under test. Under the guidance of Jesse R. Watson, the Ballistics Instrument Branch designed a special X-CZP-1 Ballistics Camera (referred to as the Watson camera) and oversaw construction of prototype units in the Michelson Laboratory machine shop.[69]

For the Watson cameras to produce photographic images of a quality that would allow comparative measurements with a mean deviation of a few microns, a short-duration, high-intensity light source and associated electronic circuitry were also needed. Ernest C. Barkofsky and the Microsecond Photography Section designed a bank of three electrical-discharge flash lamps for each camera, with the synchronization of the flashes provided by photoelectric triggering signals initiated by the projectile itself. More than 1,000 square yards of reflective sheeting (the same material that makes roadside signs visible at night) served as a backdrop for the silhouette photographs.[70]

The first experimental round was fired in early spring 1952, and the laboratory began operation the following year. In 1954 Highberg made the popular suggestion that the new facility be named for L.T.E. Thompson.[71] The notion of honoring Thompson by naming a building after him was probably one of the least controversial ideas at NOTS, but one that experienced difficulty in staying implemented. In 1951 the former Vista Del Arroyo Hotel in Pasadena had been named in Thompson's honor, but the name "Thompson Laboratories" in connection with that venerable structure was an inevitable casualty when Annex personnel moved out of the building in 1954.

By then Thompson had left China Lake, but gratitude for his contributions remained strong. After NOTS Commander Captain Frederick L. "Dick" Ashworth (later a vice admiral) officially proposed in October 1955 that the aeroballistics laboratory be named after Thompson, the request sped through channels, and in March 1956 the Chief of Naval Personnel approved the new name "with great pleasure."[72] The formal dedication and naming of the building were delayed until the following 9 November—a date selected for its proximity to the station's anniversary the day before. Thompson returned to the desert for the dedication as well as for a meeting of the NOTS Advisory Board. The juxtaposition of the board's meeting and the dedication ceremony also increased the possibility that Thompson's influential colleagues could break away from their busy lives to attend.[73]

Ironically, by the time Thompson Lab received its illustrious name, the facility was little used for the purposes for which it was designed. Gene Younkin,

U.S. Navy photo NP/45 LO5300

View down the length of Thompson Laboratory, December 1954.

U.S. Navy photo

Dedication of Thompson Aeroballistics Laboratory, 9 November 1955.
From left are Rear Admiral P. D. Stroop, Dr. L.T.E. Thompson, Dr. W. B. McLean,
and Captain F. L. Ashworth.

an employee of the Ballistics Division during the building's design phase, remembered Thompson Lab as "kind of a white elephant" whose functions were rapidly superseded. "Wind tunnels were easier to use and seemed to be the way that most people went," Younkin said, adding that wind tunnels "provided the same data, perhaps even better data, easier and less expensively."[74]

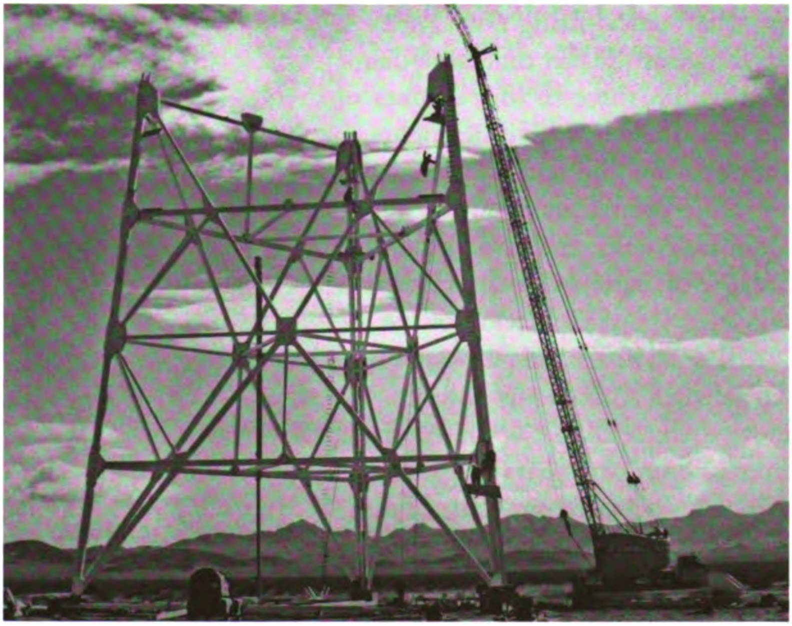
In keeping with the NOTS practice of finding uses for the materials at hand, however, Thompson Lab was used intermittently over its first few years for studies of boundary layer displacement effects and other projectile flight phenomena, then was gradually converted to office and laboratory spaces—the purposes for which it is used today. The lab is perhaps most significant, then, as a symbol of the proactivity with which the NOTS team solved unique testing problems, as well as of the pragmatism with which these facilities were adapted to other uses once the need was gone.

Randsburg Wash Test Range

One of the remotest and most specialized of the test facilities NOTS built in the 1950s, Randsburg Wash Test Range was the nation's largest test facility for accurate fuze testing in an environment similar to tactical conditions. The range was built in an isolated 15-mile-long level valley surrounded by mountains rising 2,000 to 3,500 feet above the valley floor. Not only was the terrain ideal for the range's intended use, but the sandy soil, low levels of radio noise, and low water table were also assets that would help with safe and accurate testing and recovery.

In 1950, when it became apparent that continued use of a projectile fuze-testing range at the New Mexico School of Mines would interfere with Albuquerque's commercial and military flights, BuOrd approved a replacement range at NOTS. J. A. McNeil Corporation of Los Angeles was the general contractor for an ambitious project. When Randsburg Wash opened in the southern part of Mojave B Range on 16 May 1952, it covered 320 square miles and included unusual test facilities designed to broaden the scope of the station's test and evaluation work. The initial facilities built were three specialized ranges containing gun-lines, two towers, and support facilities to allow the work begun in New Mexico to continue at China Lake.

The three ranges shared a gunline area featuring rocket launchers and 24 standard Army and Navy guns 75 millimeters to 8 inches in bore diameter, as well as buildings and facilities to support a gun target range, a vertical-firing range, and a howitzer range. Special ranges could also be set up to meet unusual test requirements. The gun target range featured twin wooden towers, plus a well-equipped instrument building, and a mobile-gun road. The two



Target-suspension tower under construction, Randsburg Wash, November 1951.

Courtesy U.S. Naval Museum of Armament and Technology

Randsburg Wash gunline with a target-suspension tower in the background, March 1952.

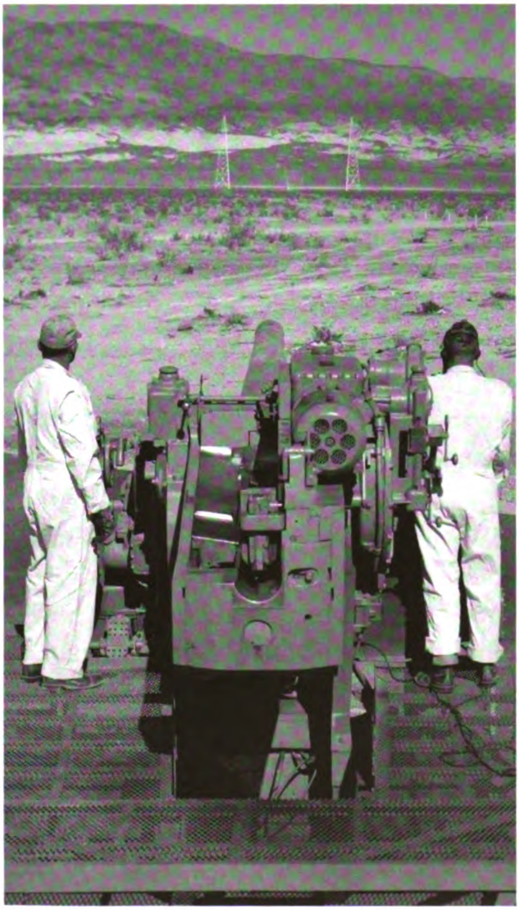
towers, located 3,200 yards downrange from the gunline area, were 357 feet high and located 640 feet apart. Pegs, not nails, held the towers together. When they rose from the desert floor in 1952, they were the tallest timber towers ever built. Each three-sided tower consisted of three independent panels, each tapering from an 80-foot-wide base to a five-foot-wide top.[75] Between the towers, targets as large as a B-29 bomber could be suspended 250 feet above the ground. A mobile-gun road made possible simulation of tactical conditions for long-range guns.

The vertical-firing range, a level 1,200-foot-diameter impact circle, took advantage of the fact that large-diameter projectiles and spin-stabilized rockets fired within three to four degrees of the vertical were stable enough that at the end of their ascending flights they usually fell to the ground base first. The rock-free soil and stiff crust of the range helped ensure that even heavy projectiles were usually buried only to depths of three to five feet. The lack of snow, frost, rain, and underground water also eased the recovery of test items. Because of those advantages and thorough spotting techniques, the test team recovered about 98 percent of the rounds fired on the range.

The howitzer range was a group of three areas designed for short, intermediate, and long-distance testing of gun-fired projectiles. The range allowed study of the application of VT (radar-proximity) fuzes to different types of bombardment firings with a variety of inert, high-explosive-loaded, or pyrotechnic-loaded projectiles. From these tests, VT fuze designers could collect accurate data on burst height, fuze-arming performance, and reproducibility of minimum arming distance or time.[76]

Power lines, communication lines, roads, buildings, and a source of water all had to be provided for these isolated ranges. A 23-mile paved road was built to connect the range with the China Lake Pilot Plant area. Range headquarters included offices, laboratories, shops, a barracks, and mess hall. Because of the secret nature of much of the work, 20 Marines were permanently assigned to security duty. About 40 engineers, photographers, ordnancemen, machinists, electricians, carpenters, and clerks, all employees of the Test Department, commuted 23 miles from the China Lake administrative area.[77]

Even before completion of the three Randsburg Wash ranges designed for projectile-fuze testing, the need arose for a remote range to test rocket proximity fuzes, work being done by the Bureau of Standards under Army cognizance. BuOrd agreed to fund additional facilities at NOTS as "extra insurance if the program expands to the point where Blossom Point is outgrown."



U.S. Navy photo NP/45 62418, courtesy Maturango Museum

Fuze test at Randsburg Wash, November 1953. Technicians atop a steel launching tower shoot a 5-inch gun past a fuze suspended from two 300-foot-high wooden test towers.

Robert A. "Bob" Appleton, head of the Test Department's Projectile Range Office and a mainstay of the testing organization, joined BuOrd, NBS, and NOL representatives on a Requirements Committee for the new range. The committee discussed adding a mobile rocket launcher and using the wooden towers then under construction, but rejected the idea because shared use would cause scheduling conflicts.[78]

Two 300-foot wooden target towers were then built 700 feet apart and 2,800 feet away from the launching tower. A 150-foot-high steel launching tower located on the level valley floor was equipped with an armor-plated control center and a 70-foot variable-angle track launcher. About 9,000 yards downrange from the target towers, the valley rose steeply, forming a 3,500-foot wall that eliminated the danger of ricocheting test hardware and helped the test team recover components.

The towers could support aircraft as large as 20,000-pound B-17 bombers 150 feet above the valley floor, a height that considerably reduced ground reflections that otherwise could distort the data to be collected during VT fuze tests. The towers were built to minimize reflections, with pegs used throughout and with targets supported by hemp hawsers instead of steel cables. Targets, were stripped B-17 bombers, F6F fighters, mock-ups of two types of twin-engine bombers, a 10-foot-diameter metal sphere, and a full-scale model of a Nakajima 97 (Japanese single-place torpedo bomber).

In a unique juxtaposition of history and technology, Randsburg Wash Range straddled the old Death Valley Borax Road used nearly a century earlier by pioneering teamster Remi Nadeau and his 20-mule teams. The flat terrain and sparse desert vegetation that once provided relatively easy passage for minerals bound for Los Angeles proved ideal for a new purpose—recovery of unexploded test rounds for postfiring analysis. The surrounding mountains, once obstacles for Nadeau and his teams, became assets, both as barriers for overshot or ricocheting weapons and as contributors to secrecy.

First Digital Data Processors

While instrumentation on the ranges brought new precision to tests, station pioneers in the computer field, notably Duke Haseltine and Alfred V. "Al" Pratt of the Ballistics Division, were also making sure that the ability to reduce and assess the data collected in those tests was increasingly sophisticated. China Lake's first centralized computer began operation in October 1951. "Push a button on the new analog computer and all sorts of things begin to happen! Red lights flash on and off—dials turn—and bells ring," announced the *Rocketeer*. The new Reeves Electronic Analog Computer (REAC), "a mechanical brain that thinks in terms of 'things' rather than numbers," was installed in the hallway next to the cafeteria in Michelson Lab.

By today's standards a clumsy device, REAC, with its 3,000 vacuum tubes, was a marvel of efficiency in 1951. Computer experts had high hopes that technical people would learn how to operate the new device—and many of them did, using the new computer for early Sidewinder simulations, calculations of the aerodynamic characteristics of the Rocket-Assisted Torpedo, and other similar tasks.[79]

REAC was an analog device, a machine that represented numbers through analogous physical measurements (of voltages, for example, or of gear or shaft rotations). As marvelous as analog devices were, Harley Tillitt knew that the new digital technology, which represented numbers by rapidly counting a series of electronic on-off impulses, offered promise of precision, flexibility, and speed only hinted at by analog calculators. After he lobbied the Research Board for procurement of a centralized high-speed digital computer, China Lake took delivery in summer 1953 of an IBM 701 Defense Calculator, the eighth of only 19 of these pioneering data processors. Los Alamos Scientific Laboratory was among the other organizations using what NOTS folks soon called simply "the 701."


TS 59-200, Facilities Review, courtesy Howard Auld

Reeves Electronic Analog Computer.

By comparison with analog machines, the 701 was expensive to maintain. For $15,000 a month—a lot of money in those days—IBM provided replacement parts and the services of four resident engineers to keep the new computer in working order. To justify the expense, extensive use of the 701 would be necessary. As Harley Tillitt supervised the computer's installation in Room 205 of Michelson Laboratory, he also began selling use of the 701 to the NOTS technical community. He reported that the computer could average 36 million arithmetic operations per hour, a speed that would facilitate "more sorting and computing than could be done by several thousand clerks."[80]

By October 1953 the 701 was up and running, and NOTS got rid of its outdated 604 multipliers. Although the 701 and its successors still accepted information on punched cards, more and more data began arriving in the form of magnetic tapes—to the everlasting gratitude of NOTS programmers, who were happy to minimize the nerve-wracking duty of walking the corridors of Michelson Lab with boxes of sorted (and spillable) IBM cards.

With missionary zeal Tillitt began a series of lectures designed to convince scientists and engineers that they could learn to code the 701 themselves and use it to solve a variety of "either short or extensive problems."[81] To help in this learning process, Bruce Oldfield, head of the Computing Branch's IBM Section, invented a program rather unfortunately termed QUEZY (actually an

Harley Tillitt and the IBM 701 Defense Calculator, September 1953.
An unidentified IBM employee points out features of the station's pioneering data processor.

abbreviation for "quick and easy"). Tillitt enthusiastically promoted the program to a highly receptive work force.[82] The 701 revolutionized China Lake's data-reduction and computing capabilities, with scientists and engineers using it to reduce data gathered from range cameras, from track-instrumentation systems, from fire-control systems under test, and even from instrumented weather balloons, as well as to perform calculations for numerous research problems.

Ever alert to new ways the 701 could be used, Tillitt himself came up with a pioneering application. In May 1954 at an IBM conference at Endicott, New York, he presented a paper entitled "An Experiment in Information Searching With the 701 Calculator." His paper, the first to suggest that the computer could be used to perform specialized library searches, told of a successful attempt to introduce automation to the Technical Library. Under Tillitt's direction, NOTS workers transcribed onto magnetic tapes the library's entire file describing 18,600 technical reports. Since information on each report was entered under several terms, the tape contained nearly 100,000 accession numbers. A researcher could obtain a computerized search of the library's entire reports collection for up to eight cross-referenced terms. Although Tillitt modestly told his Endicott audience that "the system is at present in the nature of an experiment, and whether or not it will prove to be economical or practical remains to be seen," the concept had already been well proved through searches performed over the previous six months.[83]

By 1955 the 701 was in operation an average of 16 hours a day for numerous technical and administrative uses, and Tillitt was looking into ways to use the mainframe device more efficiently by feeding it programs partially prepared by smaller input-output devices.[84] As automatic equipment increased the speed of data assessment, solutions became possible that had previously been ruled out by the expense and time involved. For example, before 1950 a worker had to spend about seven weeks to calculate one trajectory point by least-squares techniques. In 1950–1953 the card-programmed IBM Calculator did the same work in 80 seconds. The progression continued: the same job took the IBM 701 only 3.5 seconds in 1953–1957. The average desktop computer of today has many times the computational capability of NOTS' first mainframe.[85]

As the central computational capability took a great step forward, so too did automated devices to assess test data. Innovative film-reading devices, developed in the early 1950s by Robert F. "Bob" Hummer, Dave Simmons, and other AOD engineers, were among the first to digitize telemetry. The pioneering devices automatically converted film-carriage motion into digital counts recorded in card-punched form.

The specialized data-assessment mechanisms the station developed or modified during the first years of the computer revolution were a vast improvement over the old tools—but problems remained. Bruce Wertenberger,

T-Pad ground station used to receive and decode aircraft telemetry signals, G Range, 1958. From left are Warren T. Hanne, John Weber, Robert L. "Bob" Leighton, Robert "Bob" Merriam, and Howard N. "Norm" Ronning.

who arrived at NOTS as a junior professional in 1953, observed that some of these devices were "cutting edge, but very temperamental."[86] An additional difficulty was that delivery of new automated equipment often took a year or more, so that by the time the machine arrived, the need for it had been superseded. Furthermore, modifications could not easily be accomplished once the new device began its operation.

Robert W. "Bob" Herman and his Data Automation Branch had a better idea: the Naval Ordnance Data Automation Center (NODAC). By using plug-in logic packages and patchboards, computer specialists in the branch could adapt NODAC at a pace that matched rapidly changing data-reduction requirements. The new data-processing facility, which began operation in 1957, was housed in 15 equipment cabinets encompassing analog and digital bays, as well as converters allowing data to flow in either direction. As Herman expressed it, the new system could accomplish automatic data reduction "from telemetering tapes, thru analog to digital converters, thru the IBM to printed output—all on magnetic tape, no hands, no cards."[87]

By late 1957 a wire link to the IBM 704, successor to the 701, was up and running, with the station's central computer receiving and processing data from NODAC's digital side. When Herman briefed the Research Board on NODAC capabilities in October 1958, he emphasized the facility's flexibility. Terming NODAC "essentially an open-ended machine," he explained that "it will never be 'finished,' but has a growth capability for being adapted to new situations rapidly."[88]

Board members were impressed by Herman's presentation, particularly since he was able to cite an example of the speed and flexibility NODAC could bring to the data-reduction process: less than three hours after an F-104 Starfighter fired a Sidewinder 1C aerodynamic drag dummy over G-1 Range, development engineers had the reduced quantitative data from the flight's telemetry record in their hands. This record, stored on magnetic tape, was processed through a digitizing assessor, then through NODAC, and finally through the IBM 704. Early access to the data allowed test engineers to begin planning follow-on flight tests within four hours of the first test. "This is considered a highly significant breakthrough in the field of data reduction automation as it reduces the time required for data reduction from several days to several hours, and provides more accurate data than was previously possible with hand reduction methods," said the Research Board minutes.[89]

The rapidity with which information was assessed seemed miraculous to the engineers using the data. With the foresight to envision applications for the new digital tools and with the freedom to experiment, NOTS continued to develop innovative applications in the rapidly evolving computer field. Direct descendants of these data-assessment breakthroughs of the late 1950s are today's high-speed weapon systems support facilities at China Lake.[90]

From Lab to Range—Heaven on Earth

As the ranges and their instrumentation became more sophisticated, the informal "just get it done" way in which the station handled its projects continued to prove effective and highly motivational for technical employees. Charles W. "Chuck" Bernard was one of a large family of boys who had grown up helping repair automobiles in their dad's Ridgecrest garage. A member of the first graduating class at Burroughs High School, he accumulated two years of college in Bakersfield, then returned at Barney Smith's invitation to become an engineering aide. Reporting for work in summer 1952, Bernard was assigned to Don Stoehr, project engineer for the 5.0-inch flare rocket. Bernard recalled that Stoehr told him to attach a fuze to the front of the rocket. As Bernard began talking through the steps he'd have to take, Stoehr told him, "No, hey,

U.S. Navy photo

Michelson Laboratory machine shop, 1950.

just make a drawing, and we'll give it to the shop, and they'll make the parts." Bernard remembered his exultant reaction:

> Holy smokes! I got to have grown people make parts which I then got to screw together out in a little shop we had out on the range. And so it was heaven on earth because I had spent enough time in the garage to know that it took a certain amount of time to make parts. But here I could design the part, have somebody else . . . actually draw it up, and then I could take the drawing down to the shop, get the parts made, and then take them out to the range and test them. And that was the unique thing about China Lake . . . you could do a quick . . . fine-fix process because you didn't have to schedule a range someplace that was a long ways away and in some unknown area. You called somebody on the range and you said, "Hey, I'm going to do a little side test here," and they'd say, "Come on out, we'll squeeze you in."[91]

The station's cradle-to-grave weapon-development environment resulted in superior products not just because those involved were trained and experienced, but more significantly because they had opportunities to correct mistakes as they occurred and to benefit from those mistakes in subsequent developments.

"You did the whole thing yourself, and you really learned," said radar specialist John Boyle. "It was a great education to be able to be given the job, design the equipment, build the equipment with the help of some technicians and mechanics, install it on the airplane, fly in the airplane, operate the equipment in the air, then come back to ground, take the data, reduce the data . . . then try to reconcile what happened, and then feed it back."[92]

10

Leadership in Transition

When Dr. L.T.E. Thompson decided to leave China Lake, he planned for continued leadership along the path he had cleared. His chosen successor, Dr. Frederick W. Brown, possessed impressive credentials and intellect, but seemed to lack Thompson's sensitivity to the implicit boundaries of the military-civilian leadership team. The station was lucky that its commanders during Brown's early tenure—Vieweg and Stroop—were strong believers in the military-civilian teamwork and communication at the heart of the NOTS philosophy. But Captain David B. Young, who became commander in September 1953, appeared to have little more affinity for handling recalcitrant civilians than Brown had for dealing with the military.

These changes in China Lake leadership coincided with the start of an evolution toward centralization of authority within the Department of Defense, an evolution that would ultimately constrain the mavericks on the desert.

Change of Technical Director

On 1 October 1951, Thompson announced that he would retire on 15 October and that Dr. Frederick W. Brown would become the station's second technical director. Thompson planned to take a short West-Coast assignment for BuOrd, then return to the Norden Laboratories Corporation, White Plains, New York, as special deputy to the president for technical operations. He would continue his association with the station as a member of the NOTS Advisory Board.[1] The Thompsons waited until 17 November to leave the desert, giving China Lakers time to organize a farewell dinner held on 9 November in the unglamorous yet appropriate setting of the Michelson Laboratory cafeteria. More than 250 people, including eight members of the NOTS Advisory Board, came to the party. Friends and associates at China Lake and the Pasadena Annex chipped in for a gold watch. Among other gifts was a plaque from United Airlines to commemorate Thompson's having flown more than 400,000 airline miles on station business.

Why did Thompson choose to leave China Lake at the height of his success? He had already turned down several good jobs in desirable parts of the country, but this time, he said in his farewell message, an excellent job offer came along at a time when he was ready for a slower pace. He was 59 years old and his wife Margaret, never robust, had been ailing for several months.[2] Although he moved on to important responsibilities—including service as vice chairman of the Research and Development Board, as a member of several other important scientific advisory boards, and as a top consultant to the Special Projects Office—he was never again burdened with administrative duties as demanding as those he had as NOTS technical director. The report of an audit team that visited China Lake the spring after Thompson's departure described those duties as "extremely broad in scope and magnitude," requiring "the highest degree of leadership, technical knowledge, managerial experience, forcefulness, and tact."[3]

For several years before his retirement Thompson had quietly searched for the right person to step into his own shoes, eventually deciding on Dr. Frederick W. Brown, a self-confident physicist with a keen analytical mind. Brown had broad experience in academia, industry, and the public sector. Born in 1908 in Enid, Oklahoma, he earned a bachelor of science in engineering and a Ph.D. in physics from the University of Illinois. After working for the celebrated Dr. J. Robert Oppenheimer as a National Research Fellow at the University of California and Caltech, Brown taught physics at the Universities of Illinois and Kansas City. He joined the Pittsburgh staff of the U.S. Bureau of Mines in 1942, becoming supervising physicist in charge of explosives research. In 1946 he took a job as at North American Aviation, Inc., in Los Angeles.

By the time Brown left North American to become associate head of the Underwater Ordnance Department at Pasadena Annex in 1949, he had published an impressive list of journal articles and reports in the fields of theoretical spectroscopy, nuclear physics, and explosive properties of materials.[4] Annex employees had found him competent and strong willed.[5] In March 1950 Thompson had selected Brown as the station's first associate director for research and development.

Brown became the station's second technical director on 15 October 1951. Station employees, whose only technical director had been Thompson, wondered if Brown would make major changes to the NOTS way of doing business. He was known as a fervent advocate of the belief then popular among academicians that superior intellectual attainments and problem-solving approaches qualified the scientific community to be arbiters of the important decisions of government and society.[6] Would this attitude affect the way the station's military and civilian leaders worked together?

He had already made his preferences known in one respect. The NOTS organization chart showed discrete functional units, but in reality, technical projects routinely used the services of both project-oriented and functional groups to get the job done. Few large or complex projects were accomplished solely by the departments to which they were assigned. In addition, except for the Explosives Department (which received most of its tasks from the Atomic Energy Commission), the technical departments worked for a variety of other organizations in-house, in Washington, and sometimes in industry. In a speech to a local professional organization in March 1951, Brown had spoken out against the functional approach even in procurement and personnel management. His remarks, viewed with the wisdom of hindsight, hint at Brown's unwillingness to stay within the subtle boundaries that defined the technical director's job.


U.S. Navy photo, courtesy Felice Plain Mueller

Dr. Frederick W. Brown, January 1952.

In the station order under which the NOTS organization officially functioned, the commander delegated primary cognizance over all technical departments to the technical director. The top civilian at NOTS also had responsibility for "correlation and coordination of the components of the organization over which he has primary cognizance with the components of the organization over which the Deputy Commander has primary cognizance."[7] The ambiguous terms "correlation and coordination" could—and did—encompass nearly every facet of running the China Lake community as well as the technical programs. The published principles of operation adhered to Navy tradition and regulation in recognizing the commander as responsible for running the entire station, with the technical director and the executive officer (the new title for the deputy commander) holding parallel jobs directly below him. The organization chart attached to these principles (see Appendix A) more closely reflected the way the place actually ran, with the commander, deputy commander, and technical director together in a box at the top and all other elements of the organization answering to this team.

When Brown became technical director, he inherited responsibilities in delicate balance with those of his military counterpart. Thompson's quiet diplomacy had made this balancing act look relatively easy. But Brown seemed not to fully grasp the symbolic importance a smoothly functioning relationship between commander and technical director had for the rest of the station. As the prime architect and builder of the "Inyokern experiment," Thompson had broadly interpreted his own role, concerning himself with the entire spectrum of NOTS management issues—from ordnance to operating principles, from research to recreation, and from components to commissary privileges. Brown's interpretation was equally broad, but the difference was in his unwillingness to acknowledge the prerogatives of his military counterparts. "Fred Brown could see no place for military officers in a laboratory organization," according to McLean. "He felt it would be much preferable if we could get rid of all the military officers except pilots for flying airplanes, and he would rather not have them if he could get civilian test pilots."[8]

An arms-length attitude toward the military had not kept Brown from useful tenure as associate director for R&D, where his most important working relationships were with civilian scientists and managers. His effectiveness as technical director, however, would depend on establishing close working relationships with two strong-willed military men—the commander and the executive officer—who were already competently occupying some of the turf he saw as his own.

Support for Strong Civilian Leadership

In July 1951 Clarence Nickerson and his associates from Harvard returned for a second study requested by the station as a follow-up to their 1949 effort. The group again examined the relationships between BuOrd and the station, between military and civilian leaders, between line and staff managers, between Pasadena and China Lake, and between the production and development groups. The Nickerson group was in the midst of writing its findings when Thompson left.[9]

Nickerson and his colleagues again found the station "fundamentally a healthy organization," with strong working and social relationships among military and civilian employees. The group was disappointed to find, though, that multiple lines of authority still existed between Washington and China Lake. As evidence, the second Nickerson report pointed to the "many different agencies, such as the Bureau of Supplies and Accounts, the Bureau of Yards and Docks, and the Bureau of Personnel, which have cognizance over particular phases of the station's activity ***without*** responsibility for its performance as a research and development center." As long as multiple cognizance continued, "the Station will never realize its maximum effectiveness in the research and development field," the report said. Emphasizing that "the work, money, manpower, and housing program of the Station ***must be considered and planned as an integral whole***," the Nickerson group suggested that the station and BuOrd share the responsibility for that planning.[10]

The group's thinking harmonized with that of BuOrd Chief Schoeffel, who just that summer had issued a significant message to all bureau offices praising the station and its sister laboratory at White Oak as possessing a form of R&D management "superior to that encountered elsewhere in the military establishment." Schoeffel, the first naval aviator to head the ordnance bureau, had been the bureau's deputy chief when NOTS was established. He grasped the importance a strong expression of his views could have, both within the laboratories themselves and among his subordinates who were responsible for coordinating funds and tasks for the two labs. He offered a brief history lesson on laboratory philosophy:

> It has come to my attention that many of the present personnel of the Bureau are unfamiliar with the Bureau's basic policy in regard to the Naval Ordnance Test Station and the Naval Ordnance Laboratory. . . . At these two stations the Bureau has since 1946 been engaged in an experiment in the method of operating large scale military laboratories. At that time the Bureau decided to operate these two installations on the principle that the technical activities would be conducted and directed by professional civilian scientific and engineering personnel, and that the role of the military personnel would be that of providing the necessary knowledge of operating conditions plus the administration required to make the laboratory a part of the Naval Department in the broadest sense. With this in mind these laboratories have consistently been staffed with professional civil service personnel of the highest quality obtainable, under the leadership of a Technical Director in whose hands the responsibility for the technical achievements of the laboratory is placed.

Schoeffel stressed that the two laboratories depended for their smooth functioning on both parts of the military-civilian team, with each part having sufficient authority and responsibility to accomplish its share of the work. He ended with guidance the station's leaders were happy to read:

> [I]t is evident that the premises upon which the Bureau based its decision to form these organizations are sound and, since they now constitute Bureau policy, must have the wholehearted support of the Ordnance Shore Establishment. I

> enjoin upon all personnel of the Bureau who may have dealings with these laboratories to bear in mind the somewhat unusual nature of their organizations and to conduct the business of the Bureau with them accordingly.[11]

With the BuOrd chief thus on record as a champion of NOTS' principles of operation, station administrators revised the position description for the technical director's job, a document the NOTS Advisory Board considered so important that it devoted most of the board's November 1951 meeting to a final rewrite.[12] The document read in part:

> Subject only to such guidance as the Bureau gives to the Station and without further instructions from the Station Commander, the Technical Director . . . Formulates and executes the entire technical program of the Station . . . . In collaboration with the Executive Officer, assists the Commander in determining the non-technical staff and facilities required for the support of current and future technical programs of the Station. . . . He is responsible for the quality and tone of the technical program, and not only advises the Commander on the program, but actually executes it on his own initiative and in practice without instructions and review from the Commander except as to results.[13]

No doubt the Advisory Board meant the new position description to be read as a restatement of the way things had operated during Thompson's tenure. But the document could also be viewed as a license for virtually unilateral action—the interpretation Brown appears to have taken.

New TD, New Issues

Brown used his new position as technical director to launch several initiatives on which the leadership team lacked consensus. Thompson and his superiors in the bureau had agreed early on that "Naval Ordnance Test Station" was not a perfect designator for the Navy's desert laboratory, but that name-related misunderstandings were not significant enough to change the status quo. To many employees the name the place went by was part of its mystique. "Who cares what the name of the station is?" Howie Wilcox said. "We've got the job, let's go do it, and that's it."[14]

Brown, however, believed a more precise name would contribute significantly to the station's effectiveness. He pointed out to bureau authorities that the name "Naval Ordnance Test Station, Inyokern" had two things wrong with it. For one thing, after the Naval Air Facility moved to China Lake from Harvey Field in 1945, the station had no activities in Inyokern.[15] A more significant objection was that, from the beginning, NOTS had been much more than a *test* station.

An intermittent debate on the best name for the Navy's desert RDT&E center had begun before the station was established, when Captain (later Admiral) James S. Russell suggested that the place be called the Naval Aviation Ordnance Test Center, a name BuOrd rapidly modified to eliminate the word "aviation."[16] The May 1948 dedication of Michelson Laboratory, with its host of distinguished visitors, seemed to some NOTS leaders a particularly appropriate time to announce a name that fit the variety of work the new building symbolized. The Research Board discussed Warner's suggestion that NOTS be renamed "Michelson Laboratories" and agreed that "if the name is to be changed, it should be done before the dedication of the Laboratory."[17] Switzer was sympathetic, but BuOrd continued to reject renaming efforts, probably, Thompson suggested, because "people thought it was too late to get the name changed."[18]

Although many China Lakers believed the name issue was petty, others could recount incidents where funding or recruiting efforts were difficult because the name caused misunderstandings about the extent of the station's mission. Commander (later Captain) John I. Hardy, the station's experimental officer from 1954 to 1957 (and its commander during his second tour a decade later), thought the name contributed to confusion among range customers. "People in the bureau needing testing done threw a real emphasis on test," he said. "In other words people would say, 'For crying out loud, this is a test station, look at the name.'"[19]

Captain John I. Hardy

The name also occasionally made for misunderstandings in NOTS' dealings with higher authority. Early funding difficulties for the Sidewinder missile involved much more than misunderstanding the station's name, but some speculated that this confusion was a contributing factor.[20] Brown wanted to change NOTS' name to the Naval Ordnance Research and Development Center, but his efforts to implement that name proved futile. "If it ain't broke, don't fix it" describes the prevailing response both above and below him on the management chain.

Another issue Brown tackled was that of civilian housing. Again his views differed from those of the commander and most of the civilian leaders. Vieweg had devoted considerable energy to ensuring that the community of China Lake would have sufficient housing. Thompson, who believed the housing shortage to be the biggest hindrance to "development and retention of a permanent staff," had supported those efforts.[21] Brown, however, thought that civilians should not live on a military base. At first he contented himself with arguing this point in meetings of the Administrative and Research Boards. But his involvement soon expanded. By 1951 both the housing problem at China Lake and the credit restrictions that discouraged construction in Ridgecrest were easing, thanks largely to sustained efforts by Richmond and Vieweg. In 1951 Congress passed the Defense Housing and Community Facilities and Services Act, providing some benefits (for example, a federal contribution to the expense of building the Ridgecrest sewer system) for "critical defense housing areas," and NOTS authorities were successful in obtaining the categorization for the Indian Wells Valley, along with the authority to construct 350 new housing units at China Lake.[22]

Those most familiar with the base housing situation, however, were convinced that the proposed privately constructed Wherry housing area was still needed, particularly since as each new type of housing became available, pressure increased to get rid of makeshift quarters still in use. With the civilian employment ceiling at 5,000, housing authorities assigned tenants to all available quarters, filling the new houses as rapidly as they were built. Some potential China Lakers still had to work temporarily at the Pasadena Annex until housing on the desert became available.[23]

When the Eleventh Naval District Public Works office opened Wherry housing bids in July 1951, no bid came close to meeting the $6-million estimated cost. The Wherry project also encountered criticism from both sides of the entrepreneurial fence. From the viewpoint of potential builders, rigid rental controls made the housing an unattractive business deal. From the perspective of local businessmen, the Wherry landlord would have an unfair advantage in the competition for tenants. Even as NOTS management began to question whether Wherry housing made sense for China Lake, the enabling legislation quietly expired in June 1951. In September, however, President Truman extended the act by signing the Defense Housing Act of 1951.[24]

In October a North Hollywood construction firm, Hal B. Hayes and Associates, was granted an option on the NOTS Wherry project. In a survey of station residents to determine whether a healthy market still existed for the


Courtesy Maturango Museum, Bruce Bernhardi collection

Housing on Balsam Street and Coso Avenue in Ridgecrest, early 1950s.
Shown are Mynatt tract houses. Williams-Bingham and Mobilhome tracts are in the distance.

proposed homes, fully 80 percent of the residents polled preferred a location in or near Ridgecrest. To the disappointment of Inyokern residents, Vieweg decided to move the main construction site to a 175-acre parcel of Navy-owned land along China Lake's southern boundary. Construction in Ridgecrest of 350 houses in two inexpensive FHA- and Veterans Administration-financed housing tracts (Williams-Bingham houses for $6,950 per unit and Mobilhomes for $9,000 each), plus construction of 20 moderately priced homes in the same neighborhood by the Ken Mynatt Construction Company of Bakersfield, further complicated the picture. Several straw polls of the Administrative Board resulted only in the conclusion that if Wherry units were to be built, the 712 originally planned were now too many.[25]

With no good alternative available, Vieweg continued to push the Wherry project forward. Although the Williams-Bingham homes were rented or sold as soon as they became available, the sluggish market for Mobilhomes exacerbated FHA worries. Disagreements over site plans further stalled the Wherry project, and in October Richmond reported to the Administrative Board that "No actual construction is yet in sight."[26] By this time Vieweg had received his next assignment, and Brown had given Central Staff the task of studying the pros and cons of federal communities.[27]

Popular New Commander

Just as station employees were beginning to get used to a new technical director, they were faced with another reassignment at the top. After three years of excellent leadership at China Lake, Vieweg received orders to report to Oahu in November 1952 as Commander, Fleet Aircraft, Hawaii. His replacement was Captain (later Vice Admiral) Paul D. Stroop. "The Viewegs leave for Hawaii in about three weeks and seem very happy about the new assignment, although I am confident that he leaves Inyokern with the utmost regret," Captain Thomas F. Connolly wrote a friend:

> I am going to hate to see him go because we are just now beginning to have an understanding which permits me at least to believe that I could be effective under him and could benefit greatly from having his counsel and advice as I go along in this job. I can't help feeling that there will be a loss in continuity of effort and effectiveness no matter how capable Capt. Stroop is. In a sense this is inevitable in a small command.[28]

Connolly, one of a series of remarkable experimental officers, had been on the job at China Lake for just three months. He was the third member of the Annapolis Class of 1933 to arrive on the desert, his classmates having included his predecessor Captain Thomas H. Moorer and Captain Robert H. Solier, the station's executive officer. Connolly's assignment just before his NOTS duty had been as commanding officer of Composite Squadron Six, an Atlantic Fleet unit flying carrier-based heavy attack aircraft.

His background encompassed a master's degree in aeronautical engineering from MIT; extensive flight-test experience; co-authorship of a textbook on aeronautical engineering; and participation in the Gilberts, Marshalls, and Marianas campaigns of World War II. During a 1948–1951 tour at the Naval Air Test Center (NATC), Patuxent River, he had run the test pilots' school so successfully that Schoeffel, then NATC commander, annotated Connolly's fitness report with a terse yet prophetic statement, "This man is flag-rank caliber."[29]

The insights Connolly contributed to his assignment at China Lake included a talent for foresight that he used well during a brilliant naval career culminating in three stars and service as Deputy Chief of Naval Operations (Air). The trepidation he expressed about Stroop proved to be unfounded, however. Stroop arrived on the desert to face what he termed "a lecture from Bowser Vieweg," including the suggestion that if Stroop didn't agree with the NOTS philosophy of military-civilian teamwork, Vieweg would refuse to relinquish command. "He said that people that come here have got to get along with the scientists, have got to respect them, got to help support them," Stroop recalled. "And we'd tell an officer as he was checking in—if he didn't feel that way about it, why, we'd just get his orders and just let him go—didn't want him there."[30]

Stroop—who China Lake civilians fondly referred to as "P. D."—readily agreed that he could support the unusual balance of military and civilian authority at NOTS. He had never needed the trappings of authority. He had

U.S. Navy photo 7552-1

China Lake leaders at Armitage Field, 1952.
Shown from left are Captain P. D. Stroop, incoming commander; Captain Walter V. R. Vieweg, outgoing commander; Newt Ward, associate head, Aviation Ordnance Department; Captain Thomas F. Connolly, experimental officer; Ted Toporeck, head, Test Department; and Commander Dan Harrington, commanding officer, Naval Air Facility.

an ability to get along with people at all social levels, as well as a background of unusual accomplishments, including membership in the 1928 U.S. Olympic Gymnastics Team. In 1931, as a young naval aviator, he had introduced the Norden bombsight to the fleet. What he modestly termed his "spectacular luck" with tests of the famed bombsight first brought him to the attention of Schoeffel, who became an important influence over Stroop's subsequent career. During World War II Stroop accompanied Fleet Admiral Ernest J. King to the conferences in Quebec, Yalta, and Potsdam.

Assignments after the war included service as operations officer on the staff of Commander Fifth Fleet, Pacific; assistant operations officer on the staff of Commander in Chief Pacific and U.S. Pacific Fleet; executive officer of the general line school at Monterey; and attendance at the National War College in Washington, D.C. Stroop served with distinction in the Korean conflict, where, just before coming to NOTS, he was assigned command successively of *Princeton* (CVA-37) and *Essex* (CVA-9). When the good-natured Stroop encouraged his aviators to throw everything at the enemy *including* the kitchen sink, a bomb with that humble household item securely strapped to it appeared on the *Princeton* deck. Stroop posed proudly for a picture just before one of his pilots sent the unique piece of ordnance whistling down on Pyongyang.[31]


U.S. Navy photo

Captain Paul D. Stroop

Like his predecessors, the station's newest commander was handpicked to lead NOTS. As Stroop remembered the circumstances of his selection:

> Schoeffel . . . had been interested in Navy ordnance all of his life, and . . . he offered me the job to become commanding officer at Inyokern. . . . It was a place where the best the Navy had in scientific talent was gathered together, and it was a place where very competent operating naval aviators were ordered. . . . It was probably one of the finest scientific-technical arrangements the Navy's ever had.[32]

On the last day of October 1952, Stroop officially took command of the station. Assuring those present that "I have never been associated with a finer group of people—both in and out of uniform," Vieweg exhorted China Lakers to continue their tradition of excellence. "Promises of things to come are all around us. . . . This is the place, you are the people, and now is the time to turn into finished form those things you have been long conceiving."[33]

Changes in the R&D Planning Process

As Stroop began his tour at NOTS, change was also in the air in Washington. In October 1952 Brown represented the station at a national meeting of the senior scientists of the federal laboratories. Guests at the meeting included several members of the RDB, including board chairman Dr. Walter G. Whitman, the fourth in a series of able administrators to lead the Defense Department's R&D coordinating board. Whitman, who had rapidly become frustrated with the board's lack of direction and general inability to influence the R&D budgets of the three services, used the forum offered by the senior scientists to vent his disappointment in the RDB, which, he said, spent much of its time considering development projects of specific interest to the specialists staffing the board's committees and subcommittees. The RDB's committees were organized in parallel with the existing service organizations (so that, for example, BuOrd dealt mainly with the committee on ordnance), and both the parent board and its committees tended to react to existing projects rather than to consider new concepts addressing the nation's changing defense needs. "Dr. Whitman thought there should be more evaluation to guide recommendations made by RDB in the direction weapon developments should take," Brown told the NOTS Research Board. He added that Whitman saw the industrial representatives on the committee as too biased toward their own products.[34]

Whitman was not alone in his criticism of the RDB. Defense Department insiders viewed this mechanism for the administration of defense research and development as having limited effectiveness. During the waning days of the Truman administration, Secretary of Defense Robert A. Lovett sent the President a long letter recommending sweeping changes to DoD administration and operation. Lovett pointed out that the principal defense decision-making bodies—the RDB, the Munitions Board, and the Joint Chiefs themselves—were forced by law to operate under the dual handicaps of insufficient authority and excessive rigidity. Recommending that unified commands be set up to report directly to the Secretary of Defense "with the advice of the Service Secretaries and the Joint Chiefs," he pointed to the department's proliferating committees as "a very contagious virus which has the unpleasant characteristic of rapid reproduction." He suggested that the Munitions Board and the RDB be abolished, each to be replaced by an assistant secretary of defense.[35]

Lovett's letter arrived too late to do the Truman administration much good. But a new administration proved ready to benefit from the letter's recommendations. With the January 1953 inauguration of Dwight D. Eisenhower—the first Republican President in 20 years—came sweeping changes to "the entire creaking federal establishment," as the new President had promised in his campaign. Eisenhower's first Executive Order, signed on 29 January 1953, established the President's Advisory Committee on Government Organization, chaired by prominent Republican Nelson Rockefeller. Civilian membership included Lovett, Vannevar Bush, and others of equal stature who had long been involved in management and coordination of the nation's defense. Military members were Generals of the Army Omar N. Bradley and George C. Marshall, Fleet Admiral Chester W. Nimitz, and Air Force General

Carl Spaatz. Eisenhower assigned the committee a daunting task: to devise a reorganization plan that would not only make the lines of authority and responsibility within the Defense Department "clear and unmistakable" but also make defense planning and production more effective and economical.

In April Rockefeller and his committee submitted a report recommending a strengthened Office of the Secretary of Defense, with the secretary to be given command authority and control over the entire defense establishment, answering only to the President and subject only to statutory limitations. The committee recommended that the existing bilineal chain of command be replaced by "a single channel of command or line of administrative responsibility within the Department of Defense and each of the military departments," thus giving the service secretaries control over both military and civilian elements in their departments. The Rockefeller Committee also endorsed Lovett's recommendation that the Munitions Board and the RDB be abolished, with their functions transferred to assistant secretaries of defense. Six new assistant secretaries would be added to two already in existence. The assistant secretaries would not be in the "direct line of administrative authority" between the secretary and the three military departments, but would serve as his policy advisors, providing him with information to help him make decisions.[36]

On 30 June Congress enacted Reorganization Plan No. 6, one of nine executive branch organization plans the Eisenhower administration submitted that spring. Plan No. 6 focused on the Defense Department, strengthening civilian control and strategic planning and emphasizing "maximum effectiveness at minimum cost." The plan drew heavily on the recommendations of the Lovett letter and the Rockefeller Committee. With the implementing legislation, the RDB ceased to exist, and the Secretary of Defense assumed new responsibilities, including "overall direction and control . . . in the field of research and engineering," with broad powers to assign or reassign within the services the development and operational use of new weapons and systems.

By the end of 1953 most of the new defense organization was in place. The two new assistant secretaries of defense taking over tasks formerly assigned to the RDB were Donald Quarles for research and development and Frank D. Newberry for applications engineering. The unassuming Quarles, the official of most direct interest to NOTS, was experienced in defense R&D management. He had served first as a member and then as the chairman of the RDB Committee on Electronics. When he took on his new ASD(R&D) duties in September 1953, he had been president of Sandia Corporation since March 1952. During the ensuing six years of change in defense R&D

management, Quarles would become an essential change agent.[37] Newberry, the first (and only) incumbent in the ASD(AE) position, was 73 at the time of his appointment, having retired from Westinghouse six years before. The exact nature of his job was never clearly spelled out. Newberry lasted a mere four years in the post, and when he retired, the position was abolished, with most of its functions turned over to ASD(R&D).[38]

Ground Breaking, at Last

As officials in far-off Washington established milestones in the trend toward centralization of defense R&D management, NOTS leaders experienced little immediate impact. Of more pressing concern at China Lake was the Wherry housing that would allow the station to hire new employees necessary to the technical work. A Central Staff memo urged Administrative Board members to make a definite decision, pointing out that "large scale private construction cannot proceed until the Wherry plans are completely dropped rather than delayed."[39] A majority of the NOTS leadership team, however, continued to support the Wherry endeavor as the best way to provide suitable housing.

As two successive NOTS commanders worked to push the Wherry project forward, Brown continued to object to what he saw as the Navy's cosseting of civilians. "I sort of thought he was getting himself involved over in the commanding officer's area of interest," Stroop said later.[40] In April 1953, Brown went to Washington to urge the BuOrd chief to express his opinion on the matter. Schoeffel would say only that he had "no objection to having studies made just so long as we were sure we were always on legal ground."[41]

In the meantime, plans for Wherry housing proceeded at a snail's pace. While the major participants quarreled over costs, subsidies, and rents, a construction start date seemed depressingly far off. Both the construction contractor and the FHA grew skittish about the project's chances of success. But, as Stroop pointed out, "It is quite apparent someone in Washington is pressing this project very assiduously and there is still a good chance it will proceed."[42] Finally in October 1953 the Navy and Hayes and Associates signed a lease, and the way was clear for construction of a scaled-back 300 units.[43]

On 30 November 1953, a sizable delegation from China Lake, Ridgecrest, and Kern County participated in a ceremonial cutting of the NOTS boundary fence and watched construction equipment roll through the gap onto station land. The Inyokern Housing Corporation (which sometime during that month took over the construction contract) worked rapidly. The following February the Housing Office began accepting rental applications, and by the end of that

U.S. Navy photo LO 27316, courtesy Maturango Museum

Wherry housing, corner of Carricart and Segundo Streets, June 1957.

month, as plastering began on the first group of houses, 186 applications had been received. Over the next few months the Wherry houses were completed 50 at a time, and by summer's end construction of all 300 units was finished. Grateful tenants immediately occupied nearly all of the homes.[44]

Village Boycott

As the Wherry situation neared resolution, another community problem reached the boiling point when resentment between China Lake shoppers and Ridgecrest merchants built into a boycott in early 1953. This community contretemps began when the Ridgecrest Chamber of Commerce learned from Congressman Harlan F. Hagen (D-California) that the Emergency Powers Continuation Act legislation passed by Congress during World War II was due to expire on April Fool's Day 1953. Since that legislation had temporarily waived normal legislation barring civilian use of military commissaries, the prospect of the expiration was music to Ridgecrest ears.[45]

Hagen found the China Lake fence a difficult one to sit on politically, but managed to teeter there by passing along information to NOTS command as well as to the Ridgecrest Chamber of Commerce. Don Yockey remembered the quarrel as a "bitter experience" for Hagen. "I don't know how a congressman could please his constituents on a subject of that kind," Yockey said. "People weren't about to take a middle ground."[46]

As soon as the Ridgecrest merchants learned that they might gain China Lake customers, they were determined to take whatever actions were needed to make it happen. At a special 7 July meeting, the chamber's board of directors unanimously passed a motion to "go on record opposing the U.S. government entering into or continuing in competition with private enterprise including the establishing and maintaining of Commissary Stores and Navy Exchange Facilities within the continental limits of the United States" and asking for an investigation of the China Lake shopping situation. The group sent its motion in the form of a telegram to several members of Congress, several California newspapers, the commandant of the Eleventh Naval District, and the Associated Press.[47] That action sent China Lake residents into an uproar, and rumors of an impending boycott began to circulate. The China Lake Community Council held a special meeting to "go on record as opposing a general boycott of Ridgecrest merchants."[48] Brown issued a statement suggesting that "we vigorously pursue our studies to give us plans for the community that will be more subject to the control of the residents and less subject to the vagaries of political pressure and absentee authority."[49]

Faced with these reactions, the chamber backpedaled to a more moderate position, issuing a night letter on 9 July to most of its 7 July address list. Although reaffirming its original stand, the Ridgecrest group added that curtailment of China Lake shopping privileges for civilians should happen only "through a planned program which would eventually offer replacement of such facilities by private enterprise." In addition, the night letter said, "Emphasis should be given to a study of the local situation rather than an investigation as is possibly implied by our previous telegram."[50]

China Lake citizenry was not content to let the matter rest, however, and Council President Clarence Weinland, under pressure from his constituents, sent a telegram on 10 July to the same list, asking for understanding of the isolated nature of the community and the importance of China Lake's work. Hagen immediately sent Weinland a conciliatory letter:

> You may rest assured I am doing all in my power to bring about defeat in the Senate of the rider attached to the Defense Department appropriations bill, approved by the House, which prohibits the continuation of civilian commissary sales at all military installations, including NOTS. As you know, I have stated publicly that I am opposed to discontinuance of this privilege at present because of the unusual circumstances involved.[51]

In mid-July several China Lake women circulated a petition supporting the continuation of commissary privileges. "We were outraged because we were here first," Tina Knemeyer said.[52] The message Ridgecrest merchants understood was that they'd better sign the petition if they wanted to avoid a boycott.[53] Enraged chamber leaders would have been even more furious if

Commissary at China Lake, 1948.

they had known that the boycott was fomented in the home of the NOTS commander. Polly Nicol recalled:

> I can remember sitting at his [Stroop's] house, and we were all discussing Ridgecrest. The community outside had wanted to close the commissary and the exchange, but naturally that was one of our bonuses for being here. I remember LaV [McLean] and I and Esther [Stroop], maybe B. J. Patton, talking about the situation.[54]

In response to the threat of a boycott, the chamber sent a telegram on 22 July to Hagen and the state's two U.S. senators, advocating legislation prohibiting private-enterprise businesses at NOTS, a shot aimed at the "Swap Sheet," the popular weekly advertising sheet Polly Nicol and her friend, Betty Lechner, published in their base housing with permission from command.[55] The next day Hagen advised the chamber of his support and described his plans to introduce legislation that would limit the use of the commissary and prevent its replacement with another similar enterprise at China Lake.

The community council viewed Hagen's letter as a stab in the back. Hadn't the legislator agreed to back the station's position? Didn't he see that the legislation would put the citizens of China Lake at the mercy of the Ridgecrest merchants, with no guarantee of normal, healthy competition? Incensed, the council unanimously passed a resolution on 29 July condemning the chamber's actions as "strongly damaging to the interests of the citizens of China Lake, and as prejudicial to the future defense of the United States of America," then issued a flyer urging the citizens of China Lake to write their elected representatives, "advising them of our opposition to the actions taken by the Ridgecrest Chamber."[56]

A boycott of sorts was going on even as these dueling messages appeared. China Lakers, who often drove to Los Angeles or San Bernardino for major purchases, began shopping in those metropolitan areas more often. "You could go down Ridgecrest Boulevard and shoot a cannon down there. Wouldn't see anybody," said LeRoy Jackson.[57]

The next message from the chamber seems to represent an unacknowledged change in position. "Regardless of what you may read or may be told the Ridgecrest Chamber of Commerce IS NOT against private enterprise operating on the Navy Ordnance Test Station," the message said. "All we ask is that you yourself make unprejudiced comparisons and be your own judge of the results."[58]

The results soon came, but not those the Ridgecrest business group had hoped for. On 8 August 1953, the 83rd Congress passed Public Law 236, permitting continued operation of commissary stores for both military and civilian personnel living on military bases. Hagen hastened to assure *Rocketeer* readers that he was in "complete accord" with the legislation. "I sincerely regret that a great deal of bitter feeling has developed in the local community between all or part of the Station residents on the one hand, and all or part of the Ridgecrest community over this question," he said.[59] For the time being, civilians could still shop at the commissary, and Ridgecrest merchants would just have to put up with it.

Upset to a Delicate Balance

P. D. Stroop proved to be an apt student, not just of the NOTS philosophy, but also of the informal, highly social China Lake way of life. "He had a way of being friends from the sailor up to the top man," said Polly Nicol, who was often among an eclectic group joining the Stroops for social evenings. She remembered:

> Many the time after a party at the O Club, we would find ourselves headed for the Chiefs Club. . . . He would end up behind the bar, bartending, and so we always closed the Chiefs Club after a party at the O Club. I remember he always left a generous amount of money for any drinks he may have overloaded. He always said, 'That is the backbone of my Navy.'[60]

On the job too, the new skipper rapidly made his mark. "Stroop was a born leader," said Dr. Thomas S. "Tom" Amlie. "He would not chew out a subordinate for sloppy or incomplete staff work. He would simply say, 'That's a good start, now finish it.' People learned quickly that he would not accept anything but their best and would do it right the first time."[61] Indeed, Stroop encountered little difficulty in forging productive relationships with both military and civilian leaders—with one exception. Wherever he turned, Fred Brown seemed to have been there before him.

Stroop's recollection was that Brown was a fine scientist who worked hard at his job but had difficulty comprehending which decisions should be his and which should be reserved to the commander. As a consequence, Stroop sometimes faced the ticklish task of renegotiating decisions that should have been his alone to make. For example, Brown countermanded a decision Stroop had already made to put lights on the baseball field so that sailors and local youngsters could play during the balmy summer evenings. An amazed Stroop found himself in the awkward position of having to reinstate his decision. He tried explaining to Brown that one of the commander's jobs was to ensure good morale and that decisions on recreation facilities were part of this job.[62]

Communication problems between the two leaders became serious enough to warrant discussion in a July 1953 NOTS Advisory Board meeting. Thompson, disturbed by the meeting, set up a private chat with Stroop, during which the NOTS skipper expressed a high regard for Brown's ability to direct the technical program and promised his full participation in efforts to improve communication. A heartened Thompson returned to White Plains and sent Brown a carefully worded letter encouraging him to get together with Stroop for daily informal meetings, with the practical objective "to let one's hair down, but to let it down in a friendly sort of way and with some specific suggestions for action." The letter concluded with unusual bluntness:

> What I am thinking about has to do, I suppose, with the psychological foundations for human relations. Most people in positions of associated responsibilities react best when they are asked to contribute their own ideas, and when those expressions are given serious consideration, whatever their measure of expertness on the subject being considered may be. I believe you have not yet fully realized the importance of doing this.[63]

Whether Brown might have taken Thompson's advice and worked out his differences with the ever-cooperative Stroop will never be known. On a sizzling Saturday, 25 July 1953, Stroop was enjoying a relaxing swim in the station pool when his wife Esther appeared poolside, a big smile on her face. She brought news that he had been selected for the rank of rear admiral—eighth on a list of

Captain Paul D. Stroop and Dr. Frederick W. Brown on the bridge of *Princeton*, 4 May 1952.

27 selectees. Tempering this welcome news was uncertainty over whether the new rank would mean Stroop had to leave the station. "Nothing would please me more than to remain at China Lake," he assured the NOTS community.[64]

Within a month, however, he received orders for Washington, where his skills were needed on the Weapons Systems Evaluation Group (WSEG), a high-level body of experts that the Joint Chiefs of Staff and the RDB had established in 1948 as one of a series of efforts to institutionalize a science advisory system that had demonstrated its effectiveness during World War II.

Stroop was ordered to report to his new assignment as soon as possible—so soon, in fact, that there was no time for a formal change-of-command ceremony. His successor was scheduled to arrive at NOTS on 15 September. In the intervening two months, Solier, the station's executive officer, would take command.

Since Stroop's departure was of necessity too hasty for the traditional going-away rites, he instead published comments in the *Rocketeer* "regarding various phases of NOTS activity and community life." Praising the station's philosophy of operation as "very sound and productive of results," he described himself as "greatly surprised and very much disappointed" to be reassigned from a job where he believed he was just beginning to have an impact. "There are many flag billets throughout the Naval organization which I feel have less responsibility, and I firmly believe that this is the best and most important job that any captain in the Navy could hope to have," he said.[65]

Stroop also used the *Rocketeer* forum to let the citizens of China Lake know his views on the issue of civilian housing on the base. Referring to "the current study being carried on in the Central Staff concerning ultimate transition into an open community type of operation," he called mingled military-civilian housing "highly desirable . . . as a part of the overall philosophy of the operation of this Station." He added his opinion that "for the best interests of the Station, the community should remain and continue to be operated as it is presently established so long as the Navy Department is willing to continue the present type of operation."

Describing his successor, Captain David B. Young, as "a most outstanding officer and highly qualified by experience, ability, and personality, to command this Station," Stroop added ruefully that "except for my own departure, I am most happy for the people of the Naval Ordnance Test Station and for Captain Young that he is being ordered here."[66] Indeed, so impressive a candidate was Young that Burroughs had tried to give him the station's top job in 1945.

U.S. Navy photo

Captain David B. Young.

At that time, Young had regretfully declined the offer on the advice of his superior officers in BuOrd, who advised him that he needed further seasoning, particularly sea duty.[67]

A 1927 graduate of the Naval Academy, Young was one of only two aviators selected for ordnance postgraduate training in 1935. After two years of study at the Naval Postgraduate School, Annapolis, and a year of practical training in engineering, he reported to *Lexington* for duty as flight officer and executive officer with Fighting Squadron Two. As World War II began, he was working in BuAer's Development Division. He became executive officer of escort carrier *Prince William* (CVE-31) in the Pacific Theater, following that tour with a short assignment as chief staff officer, Commander Roi Island, during the Fourth Marine Division occupation of Kwajalein, Marshall Islands.

He returned stateside in 1944 to become officer-in-charge of the Aviation Ordnance Section in BuOrd's Research and Development Division, where he made the acquaintance of many NOTS projects and people. He took command of the aircraft carrier *Takanis Bay* (CVE-89) in August 1945 and was called to Washington, D.C., just half a year later to become one of an elite group of technically savvy officers in the new Office of the Deputy Chief of Naval Operations for Special Weapons (OP-06). Young became the OP-06 coordinator of naval programs in guided missiles and the alternate Navy member on the JRDB's Guided Missile Committee. In these positions he dealt frequently and effectively with NOTS.[68]

Young's next assignment was as plans and operations officer for Commander First Task Fleet. Then in October 1948 he reported to Sandia Base in Albuquerque, taking over the job of naval deputy, Armed Forces Special Weapons Project, from NOTS alumnus Chick Hayward. In May 1951 Young returned to Washington, where he held a plum job for a rising young naval officer: aide to the Secretary of the Navy. In 1952 he became commanding officer of the carrier *Bennington* (CVA-20), arriving on the desert directly from that duty in the Atlantic.

A week after his 20 September arrival, the new skipper greeted the NOTS community in a formal welcoming ceremony on the Administration Building lawn. "You may be sure that I shall do all possible to support and foster the progressive spirit that obviously prevails at NOTS," he assured those present.[69]

Seldom has a commander had a more promising start or more appropriate credentials for running the station. Yet that promise was not to be fulfilled.

U.S. Navy photo

Sidewinder-equipped F3D-1 and F3H-2 aircraft flying over Cactus Peak and the volcanic fields of Coso Range.

11

First Sidewinder Successes

U.S. Navy Sidewinder developed here at NOTS
Always hits its target with each and every shot.

. . . We grabbed it from the tester, and took it to the plane
No sense further testing, it might reject again.
But when we tried to load it upon the launcher rail
It stuck until you kicked it or hit it with a flail.

. . . It circled o'er the ranges, to wait to get a shot
But the radar operator didn't have his plot
And when they were all ready, they searched about the sky
For the drone was missing, and no one knows quite why.

. . . U.S. Navy Sidewinder developed here at NOTS
Always hits the target with each and every shot.
THAT IS—IF YOU EVER GET TO FIRE IT.[1]

As 1952, then 1953, passed, Sidewinder tests continued. Deak Parsons' unflagging advocacy brought funding and management support from the Bureau of Ordnance, and China Lakers made steady progress on technical concepts. But as Walt LaBerge's comic song testified, team members worked impatiently toward the spectacular test success needed to silence the missile's critics and vindicate its champions.

Keeping an Eye on China Lake

By October 1951 Sidewinder was a full-fledged program, but it still lacked the support at levels above BuOrd that would make the transition to production possible. Furthermore, Assistant Chief of the Bureau for Research Captain M. R. Kelley and those reporting to him in Re9 planned neither to give NOTS a free hand in project management nor to replace expended E&F funds that station leaders had previously negotiated with the bureau chief.[2] BuOrd employees complained that NOTS deliberately kept them in the dark about the day-to-day progress on Sidewinder and OMAR. In December 1951, to improve communication, Kelley sent Lieutenant (later Rear Admiral) Thomas J. "Jack" Christman, who was in the midst of a tour as Bureau of Ordnance liaison officer in Pasadena, to keep an eye on NOTS' two missile projects and report problems to Re9. Howie Wilcox recalled that Christman's first question at China Lake was how he could help. "Just figure out what it is we need done and then do it," Wilcox told him.[3]

Lieutenant Thomas J. Christman, February 1953.

Christman began visiting the desert two days a month, a schedule that rapidly expanded.[4] By January 1952 he was in China Lake full-time with the impressive-sounding title, BuOrd project officer on OMAR and Sidewinder. His duties encompassed technical, budgetary, and administrative liaison between BuOrd and NOTS on all matters pertaining to the two missiles.[5] He soon earned the trust and respect of China Lakers. He did not have extensive technical expertise, but applied his administrative skills to make meaningful contributions.

Christman discovered kindred spirits on the buoyant AOD team. He and Wilcox began punctuating their busy workdays with fast-paced lunchtime chess matches. So well-matched were the two men that neither was later willing to declare an overall winner.[6] Christman's routine included transmittal to the bureau of four copies of each piece of Sidewinder correspondence, a practice that he remembered as having "filled those guys so full of information, they didn't know what to do with it."[7] Because he wanted to buy Sidewinder the time and money it needed to reach success, his reports contained a generous dash of salesmanship aimed at his bosses in the bureau.

McLean also spent a lot of his time justifying the Sidewinder program to authorities in Washington. "He was the shield," said one Sidewinder team member. "The rest of us were allowed to work."[8]

On 11 December 1951, McLean briefed K. T. Keller in Washington. China Lakers had been dreading this meeting despite assurances Technical Officer

Moorer received from OP-51 that the review would be routine.[9] Moorer and Christman, who accompanied McLean to this session, reported that Keller still dragged his feet on increased funding, but otherwise seemed surprisingly receptive to the Sidewinder project. "When the development has reached the stage of actual flight tests which demonstrate the applicable performance of all the components and which testify to a 50-50 chance that the development warrants increased effort, then Mr. Keller will provide the increased funds for a speed-up," Christman noted.

The missile czar, true to his industrial background, advised the NOTS group that Sidewinder's prime contractor should be "someone who has more than a smokestack and a roof" and that the development team should focus on "quick elimination of alternate solutions before marriage of all of the components into the desired system." Once development engineers obtained a working model, Keller said, the missile could rapidly go forward into production. He summarized this viewpoint in an aphorism, "If man has made it, men can make it."[10]

Keller's seeming change of heart probably stemmed from the approach he and Nichols had agreed on, wherein they would avoid unnecessary skirmishes by delaying a decision on each project until the production phase. As Chuck Smith later explained, ". . . when he got to us, a decision was made that we weren't ready for production, but we were spending too little money for it to make a dent in the budget anyway, so he let us continue."[11]

McLean was relieved that opposition to Sidewinder had abated and that BuOrd approval had been obtained, but he was still concerned about the approach Kelley and his staff in Re9 had to project management. McLean believed passionately that all technical decisions must emanate from NOTS, the organization in the best position to know which decisions made the most sense. How far this view differed from that of Re9 may be glimpsed in a memorandum the station received in January 1952:

> [I]t is the intent of the Bureau of Ordnance to unburden the Naval Ordnance Test Station from some of the increased workload which is inevitable when feasibility studies are accepted as guided missile programs. . . . The cognizance of components such as fuze, launcher, warhead, and other items remain with the appropriate technical branches of the Bureau. . . . The Bureau of Ordnance will retain active control of contractual matters, even in the research and development stages, to prevent interference with other programs and to provide industrial mobilization planning coordination. Any contract in excess of $5,000 will be handled directly by the Bureau of Ordnance, acting with the advice of the Naval Ordnance Test Station.[12]

Kelley's message spelled out management procedures that an irritated McLean described as "in direct opposition to bureau policy."[13] The message was symptomatic of Re9's discomfort with the autonomy BuOrd Chief Schoeffel had promised. The bureau's research organization, lacking the authority to countermand Schoeffel's instructions, had instead reinterpreted them. As a result, a discouraged McLean faced the prospect of again making a case he thought he had already won.

In March 1952, however, Parsons, the station's most fervent advocate in Washington, became deputy chief of BuOrd. In this position Parsons could replace his behind-the-scenes influence with direct support to Sidewinder. The following month he sat in on a NOTS Advisory Board meeting featuring a briefing on Sidewinder. As Wilcox remembered that session, "I came in and Bill was at the blackboard still, and Parsons and the advisory board were sitting around, and there was a little bit of talk, and then finally Parsons said, 'All right, we'll do it. Now, I want a speed letter every week to report the progress of the project. . . .' and in a few words, he just put the whole thing on the rails."[14]

Although no successful guided test had yet occurred, he gave NOTS full technical authority for Sidewinder, thus making an unprecedented arrangement that demonstrated his confidence in China Lake. "This was a most enlightened decision, and I have always felt that Parsons was one of the very few people in Washington who could honestly claim credit for pushing the Sidewinder along successfully," Wilcox said later.[15]

Not waiting until his return to Washington, Parsons sent Kelley a dispatch from China Lake outlining the way business would be conducted:

> SIDEWINDER AND OMAR PROJECTS NEED TO BE INTENSIFIED ALONG FOLLOWING LINES X A/ FIRM UP AND CLINCH PHILCO CONTRACT X B/ INFORM PHILCO THAT MONEY ON THIS WORK IS NOT TIGHT . . . X D/ SOMEONE PROBABLY LIEUT CHRISTMAN BE RELEASED FROM CONFLICTING DUTIES AND CARRY THE BALL ON WEST COAST FOR NOTS X E/ KEEP LINES OF TECHNICAL INITIATIVE CLEAR—IN OTHER WORDS TECHNICAL INSTRUCTIONS TO CONTRACTORS CHANNEL THROUGH NOTS. . . .[16]

Three days later Re9 sent the station a Sidewinder task assignment, and an electrified Research Board rejoiced in the immediate results of Parsons' support.[17] A follow-up letter that summer officially canceled Re9's earlier instructions and gave NOTS the responsibility for "technical direction, technical control, and program planning" for both Sidewinder and OMAR. The station was responsible for all technical instructions to Philco Corporation, the prime contractor for prototype Sidewinders, and for all components for the missile except the fuze, for which BuOrd delegated technical direction to the Naval Ordnance Laboratory, Corona.[18]

Demise of OMAR

As Sidewinder gained funding and authority from the bureau, similar arrangements for OMAR were included almost as an afterthought. By early 1952 the design of OMAR's guidance circuitry was nearly complete. Tom Amlie, who would later serve as China Lake technical director, was able to demonstrate guidance with a beam he simulated on the REAC.[19] Electronic instrumentation was designed and built, microphonic and environmental testing began, and design and construction of a beam projector for the parent aircraft were finished. A redesigned airframe, EX-1, demonstrated reduced drag and increased stability.

But data from tracking runs conducted by the station's best pilots showed problems. "Reducing this data and putting it into the simulation with a function generator showed that it could not guide properly," Amlie said. "This could have been solved by gyro-stabilizing the optical projector in the aircraft, but McLean thought that was too complicated."[20] The OMAR team began to realize that only technical breakthroughs would make a reliable beam-riding air-to-ground missile possible.


U.S. Navy photo

Dr. Thomas S. Amlie.

One difficulty was that gases emitted by the HPAG rocket motor obscured the optically transmitted signals OMAR needed to reach its target. Another problem with OMAR—as with any beam-rider—was that even the smallest motion of the beam as it left the aircraft became magnified the further the beam traveled so that the missile was likely to go more and more off course as it moved toward its target. The beam itself—essentially a spotlight—spread as it got further away from its source. Furthermore, the pilot of the attacking aircraft had to linger over the target after firing to keep the boresighted optical beam trained on the target.

NOTS engineers scratched their heads over how to damp the motion of the missile in the beam without introducing too much complexity. Two decades later the Army would solve the guidance problem in its TOW (Tube-launched, Optically tracked, Wire command-link-guided) missile by sending maneuvering information over a wire. McLean had suggested trying that solution for OMAR, but, as LaBerge observed, the technology required to make such a system work was "just not ready at the '50–'52 period."[21]

In mid-1952 LaBerge, Wilcox, and McLean agreed that OMAR's problems could not be fixed, given the time and resources available. The three men recommended cancellation, with unexpended funds to return to BuOrd and the program's brainpower refocused on the Sidewinder effort. When Re9 learned of China Lake's contemplated action, according to Wilcox,

> They'd never had anything like that happen before, and they were very angry about it because they felt they had put their political lives on the line in order to get this money together for us. They thought it was very bad form for us to be sending this money back. It made them look bad. But the chief of the Bureau of Ordnance at that time said, "Thank God, there's somebody in the system who is willing to face up to a problem and send the money back to the taxpayers."[22]

Schoeffel and Parsons agreed to rechannel invaluable intellectual resources and a million dollars of OMAR funding to Sidewinder. Concurrently, employees of Eastman Kodak Company who had worked on the E seeker head for Sidewinder sought funding for a breadboard model of an optical beam-riding system that they believed would satisfy the OMAR guidance requirements.

In summer 1953 BuOrd accepted Eastman's proposal to complete development and package the components for initial missile flight tests. In 1954–1955 Eastman and Johns Hopkins University completed RAMO (reverse OMAR), a cooperative evaluation of a frequency-modulated method for coding the optical beam. The results were later applied to the Terrier missile, but RAMO itself went no further. According to Wilcox, "they finally had to give it up also because they couldn't solve the problems either."[23]

Headlight in the Sky

As the Sidewinder team made headway against the program's remaining technical and administrative roadblocks, McLean pushed those around him to look for other ways to conquer problems encountered in combat. One apparent solution was Spot, a missile system officially proposed in July 1952 by Newt Ward, then associate head of AOD. Like many such projects, the idea for Spot originated with McLean, who convinced Ward that the concept offered a possible solution to problems encountered in pinpointing and attacking targets from the air at night. The system included a simple command-control missile and a narrow-beam searchlight that shone along the missile's anticipated flight path. A controller, either in the aircraft releasing the missile or in another aircraft nearby, would keep this aerial flashlight trained on the target until the missile hit. Spot was "just a drone with a big headlight on it," said Frank Knemeyer, "and you just steered the headlight into your target—if you could find the target."[24]

Spot's first feasibility test, in February 1953, was intended to establish whether a pilot would be able to keep the searchlight on a ground target throughout an attacking dive. A landing lamp was mounted in a paper tube and installed on the bomb rack of an AD-4 aircraft. Using this makeshift spotlight, the test pilot had no difficulty in illuminating first Charlie Tower, then the sheds at the end of B-4 Track, then some earth-moving equipment at the end of Armitage Field's Runway 21. Pilots soon discovered that guiding the ersatz drone to the target seemed easy as long as the guide plane stayed behind the light. Control was effective in 14 of the 15 dives attempted. "The limiting factor seems to be the pilot's ability to see the target, certainly not guiding of the weapon," said Lieutenant (later Captain) Don Loranger. The controller, L. H. Dunning, remarked on the surprising ease with which he was able to illuminate the target, results that in two flights had changed him "from a 'doubting Thomas' to an enthusiastic believer in the system."[25]

In the next phase, Spot tests moved to small, searchlight-equipped ground-launched KD2R-3 drones. Three daylight familiarization tests established that a controller in a nearby F7F could take control immediately after the drone was catapulted. At the conclusion of these tests, though, test activity halted when the Naval Air Missile Test Center summoned the controlling aircraft back to its home base at Point Mugu for routine inspection.[26]

Once again a McLean brainstorm had reached the stage where external funding sources were needed to supplement or replace the modest E&F monies with which the project began. During a Research Board discussion of the program's feasibility, Assistant Experimental Officer Commander (later Vice Admiral) Thomas J. "Tom" Walker, who had arrived at China Lake in mid-1953 from service at Moffett Field as the first commanding officer of Air


U.S. Navy photo NP/45 6732

Spot-carrying drone on a compressed-air catapult launcher, April 1954.

Development Squadron Five (predecessor to VX-5 at China Lake), suggested that the squadron "might be able to use searchlight-equipped planes in seeking targets at the impact area near El Centro."[27] Agreeing that Walker's suggestion was worthwhile, the board decided that VX-5 would obtain more data with existing searchlights.[28]

In early May 1954 the NAMTC drone-control aircraft returned, and the project resumed with night drone tests against the massive concrete walls (Sandquist pyramids) looming in echelon on Charlie Range and offering four contiguous targets 20 feet in height and 120 feet in length.[29] One of the three searchlight-controlled drones flown in a 5 May test series struck its concrete target. Flying his AD-4B alongside, Walker judged the test a success.[30]

The final drone tests for Spot occurred that summer, with the target moved from the concrete walls to a limed bull's eye marked on the ground directly opposite the Charlie Range observation tower. Since the June moon was a mere sliver, four 40-watt bulbs shone on the target to augment natural illumination. Despite mixed test results, pilots believed the system could work. But BuOrd did not support the project, and the Research Board decided that E&F funds that had stretched over the previous fiscal year to cover several other projects were now needed to support other ideas.[31]

Reorganization and Growth

The Sidewinder team welcomed back the couple of dozen scientists and engineers—some of Sidewinder's most valuable resources—who had worked full time on OMAR. With LaBerge and Wilcox both concentrating their energies on the main missile effort, McLean decided it was time to delegate leadership of the Sidewinder program to one of them. After some discussion McLean chose Wilcox and named LaBerge the "missile engineer," responsible for coordinating manufacture of the missile hardware in both in-house and contractor shops.[32] "Walt was kind of the technical straw boss, and Howie was the front man," Amlie explained.[33]

While McLean was at it, he reorganized and renamed the divisions and branches, AOD's second and third levels of supervision. Many of the department's previous branches were now divisions in recognition of the growth AOD was experiencing. Development Division 1 under Henry Swift was responsible for continued development of Aircraft Fire-Control System Mk 16. Wilcox was in charge of Development Division 2, which had responsibility for applications of design principles, as well as for the basic technical direction of Sidewinder. Development Division 3, under the leadership of Rod McClung, was responsible for instrumentation and fabrication, studies of special fuzing problems, coil and transformer winding services, and machine-shop services. Development Division 4 under John Gregory was responsible for designing and developing AFCS Mk 8. Supporting these four divisions were two test-support organizations: Harry McPherson's Aircraft Range Division to develop, operate, and maintain AOD's aircraft ranges and Al Hoyem's Aircraft Projects Division to handle aircraft instrumentation and data collection.[34]

With full program status for Sidewinder, the number of employees in the program expanded to about 100 employees by June 1952. As the ideas reached development, then engineering development and testing phases, many more employees were necessary. By mid-1953 nine branches in five technical departments and four support branches contributed their expertise to Sidewinder. Six BuOrd offices, five other government laboratories, and at least seven contractors were also involved.[35] Although McLean preferred a small team, he knew the program had to expand as it matured.

Avion was still working on development and experimental production of the A-head seeker, but McLean reluctantly concluded that the company

Members of the Sidewinder team.

From left are Ed Swann, Lee Jagiello, Bill McLean, Howie Wilcox, Walt LaBerge, and Jack Christman.

was too small and too specialized in the R&D aspect of the work to serve as the prime contractor for Sidewinder production. Consequently, in June 1952 Philco Corporation became the production contractor for Sidewinder's guidance-and-control section. McLean encouraged Philco engineers to work toward efficiency and reliability in production, redesigning components where possible to obtain lower production costs without impairing performance.[36]

Project pilot Lieutenant Wally Schirra fired numerous dummy rounds, which he described as "still more of a breadboard than anything else." His enthusiasm and commitment to the Sidewinder project were so intense that he later admitted he was "totally convinced that the program wouldn't exist if I left."[37] Soon Amlie became Schirra's frequent passenger, riding along in the F3D Skyknight to make notes on flight tests.

After a series of captive-flight tests demonstrated the feasibility of both airframe and seeker, Wilcox and LaBerge agreed that they were ready to try an aerial test of the complete missile. Schirra was the pilot for this 21 August 1952 project milestone, a test of B-head capabilities against an F6F-5K piston-powered veteran of World War II converted to a radio-controlled drone and assigned to Point Mugu. The test was under the direction of Walt LaBerge, who Wilcox praised to a vacationing McLean as "an *excellent* test conductor." A lot was riding on the test, and Wilcox reported that "both Vieweg and [Levering] Smith anxiously asked me yesterday not to fire if we really weren't ready, but this time we were ready and that was all there was to it."

At first all went smoothly, with a strong tracking signal audible in Schirra's earphones at launch signifying that Sidewinder had locked onto its target. The rollerons also appeared to be working satisfactorily to keep the missile's roll to less than 90 degrees. Shortly after leaving Schirra's Skyknight, however, the bird veered sharply to the left and disappeared into the vast blue sky. "The signal was loud and clear before launching, but the missile showed very little observable interest in the target after launch," Wilcox observed wryly in his letter to McLean. On balance, however, Wilcox decided that this first flight test incorporating an active guidance and control section was a success: instrumentation coverage was excellent, most system components worked as promised, and the problem encountered after launch appeared fixable. "Everyone here is greatly enthused," he wrote.[38]

On September 3 the first complete round incorporating the A-head seeker was fired from an AD-4 at an F6F target. This time the missile did not guide toward its target, largely because the upper fins suddenly deflected at launch.[39] Test evidence pointed to irregular burning of the gas grain as the primary reason for the missile's failure to home, and Wilcox turned to the Propellants Division of the Rocket Department for help in improving the grain's reliability and performance. William A. "Bill" Gey, a chemist in the Research Department who had been working on Sidewinder propellant and ignition problems from the program's inception, took on the task of making 50 grains by hand to satisfy immediate testing needs.[40]

Between late September and mid-December 1952 Schirra launched four dummy missiles with B heads to obtain data on performance of the airframe, to test the rollerons, and to determine the adequacy of the instrumentation coverage. Both rollerons and airframe appeared satisfactory, but the Sidewinder team still had not demonstrated that the missile could home on its target.[41]

In Washington Parsons was anxiously awaiting news of a successful flight. So was the Sidewinder team.

From Missile Czar to Car Czar

When K. T. Keller released his findings to the RDB in March 1952, Sidewinder was not among the missiles he recommended for Kellerizing. Instead he endorsed a September 1950 paper of the Joint Chiefs of Staff that gave the Navy's Terrier and Sparrow and the Army's Nike top development priority. He also recommended accelerating these three missile programs, with a prototype run of 1,000 of each missile to be produced immediately. The prototypes would be test-fired, minor "tweaking" would occur, and production lines would then be established, each ultimately to crank out 1,000 missiles a month. Keller modeled his recommendations on procedures of standardization that worked splendidly for American automobiles, which, he pointed out, "required a period of years and millions of miles of operation to bring them to the standards of performance and reliability that we now know."[42]

China Lakers' disappointment that the missile czar did not grasp the obvious superiority of Sidewinder soon gave way to the belief that the project's failure to win Keller's approval was a blessing in disguise. "Perhaps the most important lesson is that we succeeded because we failed to be Kellerized," Wilcox later commented. "It gave us another couple of years to solve our problems."[43]

In December 1952 new evidence of Keller's opposition to Sidewinder appeared. Thompson's longtime friend and fellow NOTS Advisory Board member, Dr. Ralph A. Sawyer, ran into Keller at a business luncheon. Sawyer subsequently passed along his recollections of the occasion:

> I had an opportunity for considerable talk with him about weapon development and production. . . . In particular, he stated that he considered NOTS to be overstaffed, badly managed, and not set up to turn out engineering designs. . . . Mr. Keller also spoke harshly of Sidewinder, calling it a boondoggle which had been oversold. He said that it did not sufficiently discriminate against clouds, or have adequate engineering, and that it was not enough better than an ordinary rocket to make it worth while. I understood him to say that he was making an adverse recommendation to R.D.B. on it. If this is true, I think that you or Deak Parsons ought to get into this picture. . . . Nothing would help so much, of course, as a successful flight and I hope there will be one before too long.[44]

Station employees feared that Keller's continued ill will toward Sidewinder and NOTS might lead to further difficulties, but events in Washington soon removed that possibility. With a new administration came a thorough review of government organization, including that of R&D programs for the nation's defense. In June 1953 Secretary of Defense Charles E. Wilson directed Trevor Gardner, Air Force Special Assistant for Research and Development, to establish an expert committee to make a comparative analysis of all guided-missile programs, with the objective of eliminating unnecessary duplication.

Gardner, then only 37 years old, already had an impressive background in engineering and industrial management. China Lakers knew him well, since he had worked with NOTS during World War II as a member of OSRD's Caltech rocket team and after the war as general manager for California Operations of the General Tire and Rubber Company. Vigorous, decisive, and occasionally volatile, Gardner approached his job with evangelical zeal, his willingness to perpetuate the missile programs of all three services doing little to endear him to the senior Air Force officers on his committee. He had solid support, however, from his new boss, Assistant Secretary of Defense Donald Quarles, who also believed that more needed to be done to adapt modern technology to the needs of national security.[45] Gardner also retained strong ties with the station, notably through Thompson, who was vice chairman of the RDB and a member of Gardner's committee.[46]

The committee met throughout the summer and fall of 1953, visiting China Lake on 15 August to take a look at Sidewinder. The word from OPNAV was "that Mr. Gardner and the group are specifically interested in the hardware itself and the detailed discussion of the program and its prospects and that this discussion will go a long ways toward determining the future of the SIDEWINDER program."[47]

Jack Christman canceled long-standing plans for a week's vacation, instead hurriedly throwing together the most complete Sidewinder summary report yet written. Wilcox worked along behind him to fill in the blanks. The resulting document, *Status Report of Sidewinder Program as of 1 August 1953,* showed the Gardner Committee and other VIP visitors that, in Christman's words, "we weren't just smoke." After a favorable Gardner Committee review, Sidewinder received CNO authorization to proceed with fiscal 1954 plans for missiles, test equipment, and packaging.[48]

As for Keller, the results of the 1952 election soon sent him back to Detroit. Secretary of Defense Wilson asked Keller to stay on, but the Eisenhower administration was not willing to grant the missile czar the authority he had previously enjoyed. Keller resigned his government post and returned to Chrysler. China Lakers gladly dismissed their lingering fear that his animosity would resurface as Sidewinder reached the production phase. As soon as Keller was gone, Secretary Wilson acted on a Gardner Committee recommendation and authorized the service secretaries to approve their own missile programs in coordination with his newly established assistant secretaries. He also perpetuated the Gardner Committee under his office as the Coordinating Committee on Guided Missiles.[49]

Discouraging Test Results

Three more missiles with B seeker heads were flight-tested in early 1953, but none homed successfully on its drone target. The failures were attributed to a combination of gas-generator, fin-deflection, and servo-control problems. By then, McLean had decided to cancel work on the B head in favor of the more promising but still unreliable A head. "This was, in fact, quite a large gamble for McLean to take, since at the time . . . no single correctly functioning example of the A head existed," Wilcox later commented. "McLean never lost faith in the advantageous feature of the A-head design that made it inherently undisturbable by any rolling motion of the missile body no matter how fast or abrupt such a rolling motion might be."[50]

The first flight test of a complete missile incorporating the A head occurred on 20 February 1953. Sidewinder had performed satisfactorily in a pre-flight sled test conducted on the evening of 17 February at B-4 Track, but immediately after launch from a modified Aero 14A launcher on the starboard wing of Schirra's F3D, the bird veered sharply down and to the left. The telemetering records indicated large fin excursions that in turn generated pitch and yaw of a magnitude great enough to tumble the head gyro only a second after the missile left its launching aircraft.[51]

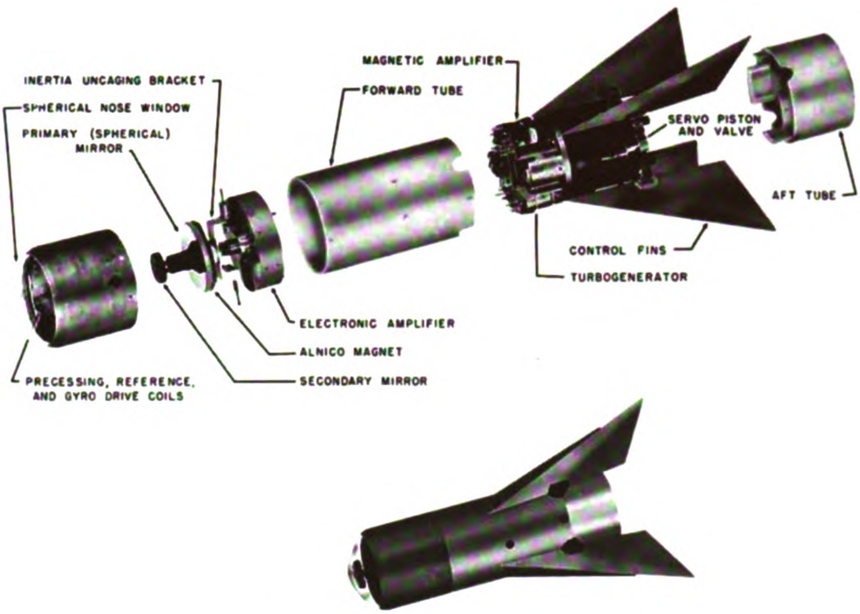
The story was the same for the next several tests. Dr. W. F. "Frank" Cartwright, a future Sidewinder program manager, arrived at NOTS that summer from a teaching job at the University of Rochester and immediately began work with Amlie on Sidewinder simulations.[52] He later recounted his vivid memories of some flight-test documentation:

> I remember going through Amlie's notes and saying, . . . "Gee, maybe I'll learn something here about how this bird works." And here was . . . this note—the entire notes from the flight test on a little 5-by-7 card written in big Amliesque letters, "Missile took off like a big-assed bird, never saw it again," signed Tom Amlie.[53]

By that time even the normally effervescent Howie Wilcox had moments of doubt. He continued to project optimistic milestones, but added that "prediction of successful firing dates is difficult and during feasibility stages generally meaningless." Nevertheless, he stood by the predictions he had made from the start that Sidewinder would successfully guide against a drone by 1 January 1954 and that an air-launched Sidewinder would guide on and hit an F6F drone at 8,000 feet range and 9,000 feet altitude by exactly six months after that.[54]

Design and Conquer

McLean had been confident from the start that the A head would win the seeker competition and that all due speed should be made toward incorporating this seeker in the missile. One big difficulty stood in the way, though—the head didn't work. Its "gyro wobble" perplexed engineers at both Avion and



U.S. Navy photo

Sidewinder control package with Type A seeker.

NOTS. "The condition is not completely understood, nor is the solution now apparent," Christman told his Re9 superiors in March 1952.[55]

"The seeker worked perfectly well as long as the source was dim," Wilcox recalled, "but when the source got brighter and brighter as the missile came in closer and closer to the target, then the gyro would go into a wildly unstable mode . . . and would lose its ability to do the job." Wilcox discovered that the head contained a prominent frequency representing the difference between the frequency at which the gyro would spin and a higher frequency at which the axis of the gyro would nutate, or vary from the vertical. Among the questions to be resolved was what if anything the difference frequency had to do with the wobble.

Various members of the Sidewinder team worked night and day on the problem to no avail. Finally in early 1953 Frederick H. "Fred" Davis, an urbane Harvard graduate who had been a NOTS employee since 1946, discovered a strange phenomenon. Wilcox recalled that he looked up from his desk late one night to see Davis standing in the doorway, minus his usual unflappability. "Howie, come on down to the basement. I want to show you something," Davis exclaimed excitedly. Wilcox put down his papers and followed Davis to a workbench on which an A-head gyro was set up and a frequency generator was putting various frequencies into the gyro's solenoid coil. As Wilcox watched,

Howie Wilcox, right, presenting Fred Davis with his five-year pin, 8 March 1954.

Davis turned an oscillator dial until he got to the difference frequency, when, Wilcox recalled, the gyro "went ape." The difference frequency was exciting the gyro wobble, but the wobble itself was at the nutation frequency.[56] Now that Davis had found the relationship between the difference frequency and the wobble, Wilcox understood how to solve the problem. He sent a memo to the members of the Sidewinder team, informing them of the good news and suggesting two possible solutions: an electronic filter that would prevent the difference frequency from being applied to the gyro precession coils or a damper that would suppress the gyro's wobble at the nutation frequency.[57] Of these proposed solutions, the nutation damper appeared more likely to work with the elegant simplicity insisted on by McLean.

Now Don Stewart took a turn at burning the midnight oil. A bright, ambitious technician with a large family, Stewart was living testimony to the democracy of the Sidewinder team, which gladly accepted good ideas from any quarter. Amlie recalled that because Stewart had 12 children, the family's washing machine "really got a workout." According to Amlie, one night as Stewart fixed the overworked machine, he free-associated ideas brought to mind by a mechanism that caused the machine to spin evenly with unbalanced loads of wet clothing.[58] He found that the nutational movements of the gyroscope rotor could be controlled by surrounding the rotor with sealed raceways, through which a minute amount of mercury would slosh to damp out the nutation. Stewart built and discarded several types of mercury dampers, finally settling on a two-race damper system that earned him a patent, got rid of the wobble, and solved the last major problem of the A-type head.[59] "Nobody knew exactly how the thing worked," Lee Jagiello commented. The important point was that it worked.[60]

Sidewinder continued to be plagued by relatively minor problems that kept success tantalizingly just out of reach. As each barrier was removed, another loomed in its place, only to be eliminated in its turn through liberal applications of inspiration and perspiration.

One problem was that the mechanical vibrations present in the missile during its flight caused the vacuum tubes to produce electrical "noise" that confused the seeker into losing track of the target. Francis McCaffrey found a way around this problem when he showed that the rollerons were the culprits. Cartwright remembered visiting the loft of a Stran steel hut behind Michelson Lab to take a look at this discovery. "McCaffrey had spun up with an air hose, a rolleron which he held in his hand, and put it on an operating seeker, and then looked at the output from the seeker, and it was indeed all noise," said Cartwright. "The rollerons on the rear end of the bird were just vibrating the heck out of the front end." The ultimate solution would be to balance the rollerons, but for the time being, since roll damping was necessary only at high altitudes, Wilcox opted for the quick fix of removing the rollerons for the missile's initial low-altitude tests.[61]

That temporary solution helped, but failures were still occurring. A minor problem can become major when it causes an entire system to fail. Thus it was with the cager pins, spring-loaded pins used to lock the gyro's caging device out of the way once the missile was launched and the gyro uncaged. As Amlie recalled:

> We'd get good signal, and we'd launch it, and it would guide during boost, and then at the end of boost, it would go blind stupid and quit. . . . these little spring-loaded pins were too small. They were breaking. When you got this tremendous deceleration from aerodynamic drag after the motor burned out, it would snap the pins, and the thing would go back and cage the gyro and pull it off the target.[62]

Fred Davis suggested a simple solution: stouter cager pins. In mid-1953 Jagiello came up with canard control surfaces that at last made McLean's torque-balance-control principle fully effective. The problem had been that as Sidewinder sped past Mach 1, the center of pressure crept forward on the control fins, causing instability. Jagiello replaced the rectangular control fins with delta-shaped ones. This accomplishment, with the addition of the stronger cager pins and the removal of the rollerons, at last allowed Sidewinder to achieve its first successful flight test.

First Success—"Essentially a Hit"

The September 11, 1953, test—the 13th in the series—started off like any other. Even the cloudless blue of the sky was unremarkable in a place where high visibility was the norm. After Avion had built the A seeker heads that would be used, they had been carefully reworked in NOTS shops by Chuck Smith and Ed Swann, along with Woody Mecham and his team of technicians. Fred Davis and Marine Master Sergeant Frederick H. Medlong had carefully assembled two test missiles, with Davis using standard gyro-caging pins and with Medlong inserting the new, stouter pins. Much care had gone into construction of the two test missiles, which were essentially hand-built, with the rollerons removed.[63]

As with all the early Sidewinder flight tests, the shot would occur over the ground ranges, extending more than 30 miles northward to the station's boundary. As with the previous dozen tests, the target was an F6F-5K Hellcat drone, which carried both cameras and telemetry equipment. The launching Skyknight also carried high-speed cameras to film the missile's launch and flight. On the ground, a variety of instruments—cameras, cinetheodolites, SCR-584 radars, plotting boards—were set up to track every instant of the test. Despite this instrumentation, equipment breakdowns, weather conditions, personnel problems, or a combination of negative conditions could—and sometimes did—result in inadequate data. The September 11 test was no exception.

As the pilot heard the growling seeker tone in his earphones that meant Sidewinder had locked onto the target, he pressed the pickle and fired the missile Medlong had prepared. The Sidewinder appeared to dip away from the target drone, then immediately to climb, veering toward the right side of the vertical stabilizer on the drone's tail, apparently missing that target by mere inches.[64]

Wilcox was in Tower 5 overlooking G-2 Range, where he could get a good view of the shoot. The test encounter happened with a speed that made results hard to see, but Sidewinder obviously had not hit the drone, still flying along undisturbed. The men in the tower agreed, though, that the missile had passed extremely close to its target. Cartwright, who said that he was frequently astonished by the air of confident optimism exuded by Wilcox, had special occasion to be astonished that day. Cartwright remembered the test:

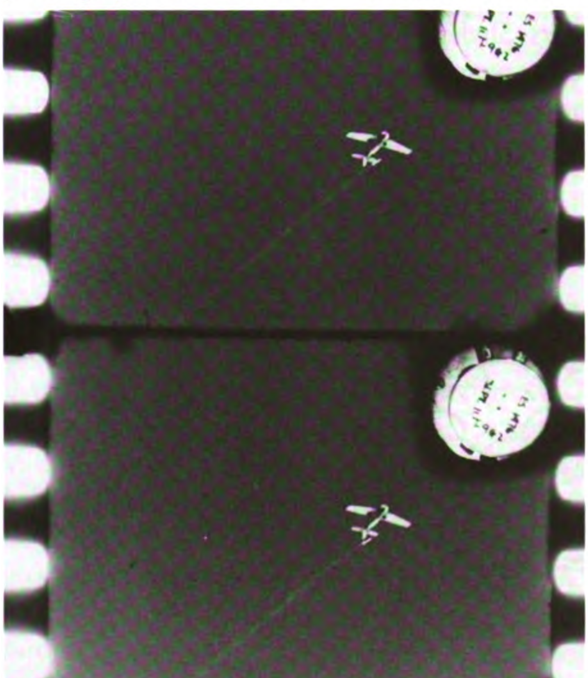
> The bird gets fired, comes very close to the F6F, and Howie picks up the phone and gets BuOrd, and tells them, it must have been within 10 minutes, "It was a six-inch miss." How can you possibly tell a six-inch miss from one direction? I've asked him that several times, and he says . . . it's gestalt, it's E.S.P., he knew. I think it turned out to be one and a half feet. . . . So there was one hell of a lot of competent confidence.

In hopes that the data would support that confident prediction, test participants crowded into a small conference room to inspect the test films.

Cartwright recalled that the Test Department rushed the footage to the in-house photo lab and that Lieutenant (j.g.) Kenneth J. Powers, then Christman's assistant, was dispatched to retrieve the film the instant it emerged from the developing solution. Clutching the dripping film, Powers sped into the conference room, hurriedly threaded the reel into a cumbersome Mitchell projector, and began showing the precious footage to McLean, Wilcox, Chuck Smith, and other project members. Cartwright recollected what happened next:

> Howie's saying, "Keep going, keep going," . . . and you'd see the missile going through the air, and then here would come the drone, you'd see the missile coming up on the F6, and as it got close to the F6, Howie would say, "Wait, stop it! Stop it!" So Ken Powers stopped the projector, and everybody crowded up to the screen to see how far from the tail the missile was. And as we watched, close to the screen, everybody crowding around, from the middle of the frame, a hole appeared, and gradually grew as the Mitchell . . . burned up the frame with the data in it, at which time, Christman turned to Lt. (j.g.) Ken Powers and said, "Powers, when you leave, you leave your balls on my desk!"[65]

Thus important evidence literally went up in smoke. Fortunately, other photographic test data existed, and McLean and the others saw enough to feel confident that the missile had successfully guided on the target. "It would have created a fuze function if we had an influence fuze," Wilcox said, "and it would have had a solid kill if it had a warhead." With this reasoning, he called the results "essentially a hit" and followed up on his phone call with a jubilant wire confirming the shot's success. "Nobody can ever tell me that 13 is an unlucky number," he said.[66] Subsequent test data confirmed this perception, and the minutes of the next Research Board meeting noted:



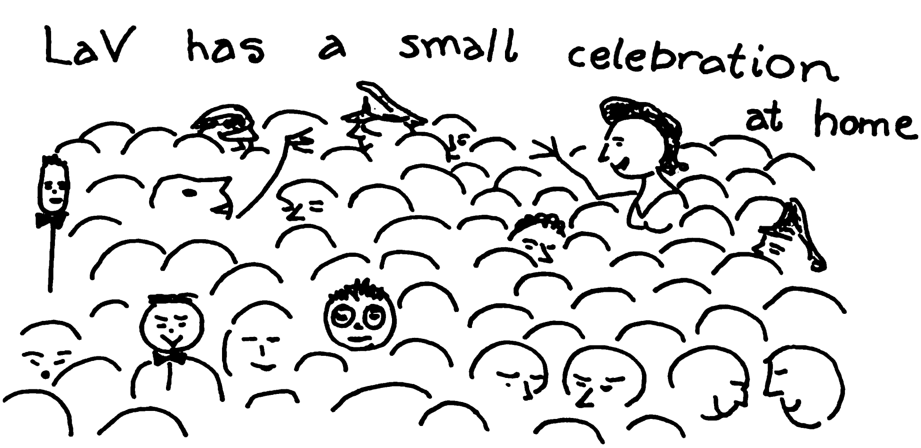
U.S. Navy photo NP/45 62381

Footage from 11 September 1953 Sidewinder test. The missile is shown narrowly missing its F6F drone target.

> [I]nformation was received which shows a miss distance of 11 feet from interception of fuselage and trailing wing edge of drone with the missile passing 11 feet above and 1 foot to the right of this reference point. The missile passed approximately one foot away from the right side of the vertical stabilizer of the tail at a vertical height within the dimensions of the stabilizer.[67]

Late that 11 September afternoon someone thought to notify LaV McLean that a significant milestone had been reached. Since her husband brought home almost no information about his work, she had known only that important tests were absorbing a lot of his time and attention. Nevertheless, the words "it worked" were enough for her to decide to have a party. What ensued that evening was perhaps the most celebrated of her famous backyard barbecues, an event Howie Wilcox considered so special that he later included "LaV has a small celebration at home" in a cartoon strip he drew to depict Sidewinder milestones.[68]

As the evening wore on, the partygoers began thinking about who else might like to know about the day's events. LaV McLean placed a call to P. D. Stroop, forgetting in her enthusiasm the time of night in Washington, D.C., where NOTS' popular former skipper was staying with an Annapolis classmate pending his assignment to quarters. Shaken awake by his groggy host, Stroop stumbled downstairs to the phone, wondering what emergency warranted a phone call in the middle of the night. He picked up the receiver and, just making out a voice over raucous party noises, he gathered that something



Courtesy Evelyn Wilcox

LaV McLean's famous bash after the first successful Sidewinder test firing.
Among the participants shown in this Howie Wilcox cartoon are a stick-thin Walt LaBerge, a rotund Wilcox, Bill McLean in glasses, and the fabulous hostess herself.

important had happened at China Lake. Someone levelheaded could enlighten him, he thought, so he asked to speak to Polly Nicol, the most sensible China Laker his sleepy mind could come up with at that moment. "Polly can't come to the phone," LaV informed him. "She's on the roof!"[69]

The celebrants waited until a more reasonable hour to notify Parsons of the day's triumph. As the program's chief advocate in Washington when that support had been politically inexpedient, Parsons had turned a confident face toward the missile experimenters at China Lake. Now his congratulatory note was also a sigh of relief:

> I am delighted to hear the news on last Friday's SIDEWINDER flight. . . . During our many months of waiting for confirmation I have naturally raised the question as to whether our approach and emphasis had been right. I always came back to the conclusion that hindsight confirmed the 1952 decision to "give it a whirl" . . . Congratulations and more success to you.[70]

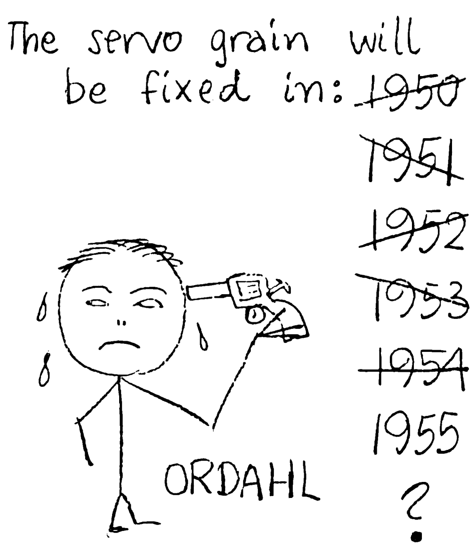
McLean also called Thompson, who responded to the news with "some of the most pleasant feelings I have had in a long time." In Thompson's glowing follow-up letter, he predicted that "this system will turn out to be one of the most important in our arsenal."[71] Gratifying as this praise was, the Sidewinder team knew they had a lot more work ahead to make the missile reliable enough to enter operational status. Within days of that first success, Wilcox wrote a memo detailing the tasks to be accomplished. Despite the length of the list, he stuck to his confident prediction that Sidewinder would enter the fleet on New Year's Day, 1956—scarcely two years away.[72]

The Gas Generator Problem

Even as the debris from the McLeans' bash was being cleared away, the Sidewinder team was hard at work again. Cartwright studied the telemetry data from the missile's first successful flight and found discomforting evidence. Sidewinder had been headed straight for its target, then the electrical generator abruptly stopped functioning, so that the missile was simply coasting along its ballistic course as it neared the drone. The missile began tumbling, then fell back through the target area. At that instant power suddenly returned, thus enabling the seeker to lock again onto the target. Cartwright figured out that the heat of the propellant grain melted the inhibitor, which flowed over the grain's burning surface and put out the fire. After boost, the inhibitor burned off, the gas generator (propellant driving a turbo alternator to provide Sidewinder's power) started burning again, and the electrical generator came back on, allowing power to return just as the missile was above its target. Although the missile was able to home again just in the nick of time, Cartwright knew that such a lucky accident could not be depended on to happen again.

That was not the first time the gas generator had caused a power malfunction. Chemical engineer Douglas D. Doug" Ordahl, an expert in the physical properties of solid propellants, had already looked into numerous possible solutions. Indeed, in their status report just the month before, Wilcox and Christman had mentioned the gas generator's disappointing performance. "To date, 92 types of fuel grains, of both American and British design, have been evaluated," they said.[73]

An ammonium-nitrate-based inhibited grain invented by Bill Gey in 1950 had several serious deficiencies, but it was the best alternative available at the time. The station's propellant specialists later developed the slow-burning, double-base X-9 propellant specifically for Sidewinder, and by 1953 Sunflower Ordnance Works was delivering large quantities of the new propellant to China Lake. The new propellant burned cleanly, thus eliminating solid matter that might obstruct servo orifices. In more than 500 static firings specifically testing the parts of the missile's servo unit involving the generator and the passage of gas, X-9 functioned perfectly between -65 and 165°F.[74] Despite X-9's success, however, a clean-burning propellant didn't provide the entire solution. Ordahl recommended changing the materials used for the inhibitor and reversing the direction of the extrusion to avoid the possibility that preexisting imperfections in the sheet of propellant would line up with imperfections introduced during extrusion. With adoption of these recommendations, the gas-generator problem was fixed—or so everyone hoped.



Courtesy Evelyn Wilcox

Wilcox cartoon showing Doug Ordahl's frustration with repeated attempts to solve Sidewinder's gas-generator problem.

The problem recurred so often, however, that it became part of Sidewinder lore. After each failure, an increasingly frustrated Ordahl worked to improve the gas generator's reliability and consistency. "It was a simple concept, but it had all kinds of problems like the exhaust gases, and the inhibitors, and things like that, which you wouldn't normally think of as being a problem," said Dr. Edward E. "Mickie" Benton. If the heat of the gas-generator exhaust didn't short out the delicate electrical leads in the back of the missile, small metal particles in the exhaust were just as likely to evade their filtration system and block the orifice in the servo-manifold space.[75] Ordahl finally developed an inhibitor that solved Sidewinder's gas-generator problem. But, recalled Wilcox, "Many tears were shed before that happy event occurred."[76]

First Direct Hit

In November 1953 Wilcox presented a score card to the Research Board:

> Fourteen missiles have been fired to date, three of which have demonstrated guidance. On the first of these, the gyro recaged in the last second of boost due to a malfunction. The second missile to be fired was successfully guided all the way and missed the target by one foot. The third missed the target by 27 feet off the right wing tip.[77]

Guidance had been demonstrated, but the Sidewinder team would not be satisfied until the missile hit its target—a success that came on 9 January 1954.[78] For LaBerge and the test-preparation team, the day started with some last-minute adjustments to the missile. The test used a seeker manufactured by Philco and modified in the station's shops.[79] The QB-17 drone target was borrowed from Nellis Air Force Base. Because those in authority in the Air Force didn't think Sidewinder could hit its target, they were willing to let scarce and relatively expensive B-17 bombers be used as drone targets. So confident were Air Force pilots that the missile would miss that they supposedly even offered to fly the aircraft themselves.

As Sidewinder streaked from its host aircraft, the missile temporarily lost voltage during the boost phase, but power returned an instant later. The round maneuvered, locked on the infrared radiation of the drone's starboard engine, then entered the starboard wing from below. Because the test missile had no warhead, it didn't explode, but it did plenty of damage.[80]

On the way home from Saturday grocery shopping, McLean saw the fire trucks rushing to Armitage Field and was able to get to the scene in time to check the results. Air Force personnel brought the crippled drone aircraft in for a landing, but with a great ugly gash in the wing and a mangled, twisted blade marking the missile's path of destruction. According to McClung, who was there to oversee the telemetry, Sidewinder's inventor appeared disappointed that his missile, even without its warhead, hadn't destroyed the drone. Turning to an Air Force officer, McLean asked, "What does it take to bring one of those

U.S. Navy photo LHL 182712/3

QB-17 drone at Armitage Field after sustaining damage from Sidewinder's first direct hit, 9 January 1954.

down?" The officer replied, "Don't worry about it, Doctor. They don't make them that way anymore. Your missile will bring down a modern one."[81]

The Air Force then made it clear that all bills for drone damage would be the Navy's to pay, and a few days later NOTS delivered the Navy a big, but welcome, bill. Sidewinder again streaked toward its drone target, and this time the documentation cameras captured a tiny flash and a puff of smoke. The drone, with part of a wing destroyed, went spiraling down toward the desert sand. Gravitational forces ripped the other wing off, and the fuel tanks ruptured to turn the drone into a flaming torch falling from the sky. "Oh, it was spectacular," said Mickie Benton. "I didn't get to see it in real life, but I did see all the movie reruns. We reran and reran that picture time and again."[82]

Those first successes bred more, and with feasibility no longer in doubt, attention could shift to the many daunting tasks associated with readying Sidewinder for its fleet introduction.

12

Polaris, Pilot Plants, and Penetrators

Those who lived and worked at China Lake took for granted that they would not know about certain aspects of what went on there. The most secret work occurred at the Salt Wells Pilot Plant, the sole producer of certain chemical explosive components for the nation's atomic weapons between 1945 and 1949. Until 1954 Salt Wells was still a major producer, but its main contribution was in the transfer of its production techniques and know-how to other plants.

In a significant contribution to national defense, a NOTS study of the Navy's special-weapons program led to a major change in the course of the naval fleet ballistic missile program. China Lakers also contributed expertise to several other nuclear weapons.

Salt Wells Secrets

The nation's ability to split the atom made a profound difference at NOTS, not only because the blinding flash of an A-bomb test at the Nevada Test Site could be seen 150 miles away at China Lake, but also much more directly.[1] During the station's first decade, the AEC funded 15 to 20 percent of the entire NOTS budget. In return, the station performed services crucial to the development and manufacture of non-nuclear explosive components for the Manhattan Engineer District (or Manhattan Project). Nearly everyone in the Indian Wells Valley knew someone who commuted to a mysterious job over the shoulder of the Argus Range. That secret work, code-named Project Camel, took as many as a third of China Lake's workforce to Salt Wells Valley, site of an arid pluvial lakebed and of the Salt Wells Pilot Plant (SWPP).[2] This most secret of NOTS' wartime facilities had been built in a hurried six months starting in July 1945 to melt, cast, and shape precision-machined high explosives, called explosive lenses, that surrounded and crushed the core material of an implosion-type atom bomb.

In November 1945, when Caltech had turned its Salt Wells equipment and responsibilities over to the Navy, many of the SWPP scientists, engineers, craftsmen, and plant operators had elected to stay on as civil servants. Salt Wells continued to operate as the nation's principal plant for production of

U.S. Navy photo NP/36 002069, courtesy Ridgecrest Chamber of Commerce

Project Camel crew at "Ye Olde Coffee Shop," Salt Wells Pilot Plant, January 1949.

the explosive components of atomic weapons. In turn the Manhattan Project provided NOTS with generous funding support, pouring some $4.7 million into community facilities between 1946 and 1948. Those funds paid for Groves Street School, which accepted its first pupils in 1948, as well as for bachelor and family housing, an enlargement of the commissary store, the barbershop, several utility lines, and an extension of the runway at Armitage Field.[3]

By 1948 Salt Wells' contribution to A-bomb technology was changing. Rapid development of explosive lenses, so critical to the wartime creation of the "gadget," now needed to become less of an art and more of an industrial process. While Salt Wells continued to produce explosive lenses, its main value became innovations that allowed lens composition to be more closely controlled during the manufacturing process.[4] That new work resulted in more hiring and further construction of facilities so that the plant's capacity actually increased during 1948–1949. A second melting and casting line, permanent test firing facilities, temperature-conditioned explosives-storage capacity, security fencing, and lighting were added during these years. In summer 1949 employment at Salt Wells reached its high point, with 700 people working at the pilot plant itself and approximately 300 more required in supporting departments.

By that time, shipment of the explosive lenses had become a fairly routine matter. Because rail shipments presented a potential security risk, the AEC asked the Air Force to carry out air shipments using C-54 aircraft. So began the Salt Wells "Milk Run," an operation maintained steadily by a crew of 19 for more than five years. China Lakers were curious at first about the big planes with the red tails and Air Force markings, but the comings and goings were so frequent that they soon became part of the routine. The Milk Run continued even when some of the team were diverted to the Berlin Airlift in July 1948–May 1949.[5]

As the work at Salt Wells changed to emphasize process engineering, NOTS expertise helped the AEC develop manufacturing processes elsewhere. Beginning in 1947 Salt Wells and the Pasadena Annex assisted the AEC in the design of a large plant built in Burlington, Iowa, to be operated by Army Ordnance for the production of explosive lenses. Employees of the new plant received training at NOTS in the necessary high-explosive processes. Significant contributions to Burlington's processing equipment were developed at Salt Wells, fabricated at the Foothill Plant of the Pasadena Annex, and shipped to Iowa for incorporation in the new plant.

Just as he had during World War II, Bruce Sage continued to manage both China Lake and Salt Wells Pilot Plants under the broad umbrella of the Explosives Department. Through 1948 and into 1949 SWPP employees maintained the secrecy—and long hours—that had prevailed during the war. The AEC allowed a discreet glimpse through the veil of secrecy surrounding its relationship with Salt Wells in August 1949 when the existence of this relationship was declassified from "Secret" to "Restricted Data."[6]

After Sage became associate technical director for engineering in September 1949, Levering Smith became acting head of the Explosives Department. As the man in charge of Salt Wells, Smith had unusual authority to make decisions. "I was in the Civil Service position, but I also had another role as military advisor to that position," he said, "so I could advise myself."[7]

By 1950 Salt Wells needed new facilities and additional personnel to meet the AEC's demand for precision in plant operations. That October Captain Carroll L. Tyler, manager of the AEC's Santa Fe Operations Office, accepted

U.S. Navy photo, China Lake archives

Dr. Bruce H. Sage.

the station's request that the commission provide funding for more than 26 percent of the housing and community services needed by military-civilian employees at China Lake. This agreement resulted new motel-like U-shaped bachelor units and two- and three-bedroom duplexes in the northeast corner of the community.[8] The AEC not only paid its own way at Salt Wells, but also furnished overhead support to pay for an equitable portion of the services supplied by other NOTS departments.[9]

During 1951–1952 extensive additional facilities were constructed at Salt Wells for precision machining of high explosives and for other necessary processes. Also added were shops, administrative spaces, and a cafeteria that eliminated the need for employees to spend work time driving back and forth to the nearest service area at CLPP.

In fall 1952 the AEC and BuOrd restated the SWPP mission to emphasize applied research, development, and process engineering carried out through pilot production. The scale of operation at Salt Wells demonstrated the overall economy of an intermediate stage between the applied research phase and the manufacture of high-explosive components.[10] As the mission at Salt Wells changed, so did the management. By the time Sage went back to Caltech in 1950, the concept of operating both SWPP and CLPP in one department was not working as well as it once had.[11] The high security-clearance level needed at Salt Wells made movement between the two sites difficult, and with the distance between the two plants several miles apart, administrative people lost valuable time trying to represent both plants equally. Furthermore, CLPP employees objected to the higher priority placed on Salt Wells. In January 1952, when Thompson moved Levering Smith into the position of associate director for research and development, the Research Board split the Rockets and Explosives Department in two, with Rocket Department leadership going to Emory Ellis and Explosives Department leadership to Paul A. Longwell.

Longwell shared with Ellis the distinction of membership in the small fraternity of Caltech men who had worked at NOTS from the start. The quiet, competent Longwell had earned a master's in chemical engineering in 1941 and had begun full-time work in the Caltech rocket project in Eaton Canyon in 1942. He was one of the designers of the Salt Wells plant and was in charge of operating the plant from May 1945 on.

According to Kenneth H. Robinson, who became the Explosives Department's associate head, Longwell had "a great talent for problem solving in new fields" and was "more geared to the analytical approach" than Sage had been. "Paul was able to inspire an unswerving loyalty among the scientists and engineers working under great pressures," Robinson said.[12] A Caltech man himself, Robinson had a master's degree in civil engineering and a somewhat unusual leadership qualification: he had worked for 12 years as assistant headmaster of the Catalina Island School for Boys. In July 1942 he too went to work at Eaton Canyon, where he was in charge of procurement. He and his wife Liz arrived in China Lake in December 1945 and rapidly became indispensable to the social life of the community.[13]

While process improvements at Salt Wells continued under this new leadership, the station was also pursuing new developments designed to apply NOTS rocket and propellant expertise to new weapons designed to capitalize on the potential of atomic energy.

Atomic Rockets

In late 1950 the AEC called on China Lake's broad knowledge of rocket technology and established reputation within the atomic establishment to assign the station a huge two-stage experimental weapon designed to test whether a solid-fuel surface-launched rocket could deliver a nuclear warhead. The request that the station conduct the program came from the AEC's Carroll Tyler, a former shipmate of Levering Smith's. Under an informal arrangement between Smith and Tyler, the AEC provided the funding for the weapon, with the project to be completed within six months. The nuclear device Tyler wanted to loft was relatively small for that time, but it would still need to carry a payload weighing thousands of pounds.

Because the 50-foot monster would be "far and away the largest rocket that NOTS had tested," Levering Smith named the weapon Big Stoop, after a comic-strip character with enormous feet.[14] Smith reassigned four of the best rocketeers to the job. This tiny team worked behind a locked door, with hardware leaving the room covered by a black shroud. According to Barney Smith, an important member of the team, these security measures served primarily to arouse the curiosity of other employees. Still, he said, "The project went along smartly because there were so few involved."[15]

The time to develop Big Stoop was so short that he turned the usual progression of events around, beginning his work by writing a final report that projected the sequence of events and lacked only the details of the data. "That fictitious report became the project plan," he recalled. "As each firing took place and the data was reduced, we simply filled in missing numbers in the tables, graphs, and text."[16] The group cobbled together an imposing two-stage rocket made up of two solid-propellant motors developed by Allegheny Ballistics

Laboratory for the Bumblebee program. Big Stoop flew about 20 miles on each of three test flights in 1951. So cautious were the test conductors that before each test the residents of the small mining town of Darwin, just north of the station's boundary, reportedly had to vacate their homes temporarily.[17] The test rockets flew successfully on their prescribed course, and Tyler was convinced that Big Stoop's range could be extended beyond 40 miles with little difficulty.[18] Within a week of the last firing, the final report was delivered exactly on deadline.

Work on Big Stoop, however, did not go beyond these demonstrations of feasibility. In early 1952, at Levering Smith's suggestion, the Navy turned over cognizance of the program to the Army, which was developing Honest John, a somewhat smaller, shorter-range rocket designed to carry the same atomic warhead.[19] Like many another short-lived program, Big Stoop had implications for work to follow. In this case, Smith said that the success of the two-stage motor concept later gave him confidence in the two-stage concept for the Polaris missile.

The station also applied its rocketeering expertise to development and testing of nuclear weaponry. Project Airedale, a little-known NOTS contribution to the nation's understanding of radioactive fallout, began in 1950 when the University of California asked NOTS for help in designing a rocket that would sample atomic clouds. Specifications were for a 5.0-inch rocket head with a filter, a sample chamber, and valves that would seal the chamber on impact to safeguard the sample obtained.

Ted Lotee, whose NOTS career started in the Ordnance Section of the Explosives Department in 1947, recalled that Hugo Meneghelli, head of the Rocket Division, Rockets and Explosives Department, "sketched the first designs of that head in the dust on the hood of my Jeep station wagon" in a successful attempt to get Lotee involved in the project.

In April 1951 Lotee took a group of three China Lakers to Eniwetok for Project Airedale's Operation Greenhouse. The group was there for six weeks and saw three atom bomb explosions at close range. Despite valve failures that contaminated many of the particle samples collected at the atoll, the four men collected enough data to be able to state with confidence that rockets could be used to sample atomic clouds and that further rocket-head development could produce an effective sampling vehicle.[20]

The station had the leeway to do that sort of project during its early decades, Lotee added. He and others also routinely worked on explosive trains, fuzes, detonators, and igniters—anything necessary to get the job done.[21]

Elsie Development and Testing

Beginning development even earlier than Big Stoop was Elsie, another postwar atomic weapon. Following the underwater Crossroads Baker test at Bikini atoll on 25 July 1946, the Navy began considering development of an armor-piercing bomb for subsurface detonation against armored ship decks, underground bunkers, and reinforced submarine pens. Work on the bomb began in the face of an unresolved quarrel among the military services over whether to develop big strategic weapons or small tactical weapons.

Although the Navy, Army, and Marine Corps supported the development of relatively lightweight, relatively compact gun-type atomic weapons, the Air Force argued that these weapons wasted fissionable materials that otherwise could be used in large implosion-type strategic bombs. The gun-type weapon, designated "Little Boy," had an inherently lower explosive yield-to-weight ratio than did the Mk III "Fat Man" implosion type of bomb. Furthermore, the gun-type projectile and target assembly used two or three times as much of the scarce U-235 as did a comparable implosion core. In addition, Little Boy's timing of nuclear initiation (the introduction of "seed" neutrons to begin fission) could not be as precisely controlled so that the possibility of premature explosion was increased. On the other side the Navy argued that the gun-type weapons were inherently simpler and more robust with better performance against fortified targets, particularly underground where the "earthquake effect" of a penetrating weapon could destroy even deeply buried and heavily reinforced structures.

The Weapons Subcommittee of the AEC General Advisory Committee agreed with the Air Force position and decided in May 1947 to postpone development of a gun-type weapon and focus attention instead on improving larger implosion weapons. The RDB's Committee of Atomic Energy disagreed; in October 1947 the committee recommended that BuOrd facilities be used in the study of a gun-type penetrating weapon. The following April the Military Liaison Committee (MLC) to the AEC seconded that idea, requesting that the AEC undertake development of a penetrating weapon, using BuOrd facilities to develop the non-nuclear components. Los Alamos suggested that the Naval Gun Factory design the ordnance components. By July 1948 the new weapon was being called Elsie, shorthand for "Little Child" (L.C.), a nickname evocative of the weapon's relationship to Little Boy.

The station's work during World War II on the A-bomb's explosive components had given NOTS a reputation in the atomic community as a place where ordnance problems were attacked with vigor and professionalism. In particular, Parsons, who had been a member of the MLC ever since its formation in April 1948, was a consistent and influential advocate for NOTS. As a result, the station was soon involved in the development of the Elsie aero- and hydrodynamic configuration, as well as in structural design of the weapon's non-nuclear components for water and earth penetration.[22]

U.S. Navy photo, courtesy Felice Plain Mueller

Franklin H. "Frank" Knemeyer, October 1956.

The first version NOTS designed became known as the TX-8 bomb with the station code name Project 324. The Underwater Ordnance Department took on program management, with support from the Ballistics Division of the Research Department. Because the objective was to use Elsie for both earth and underwater penetration, the hydrodynamic test work was conducted at the Pasadena Annex's Morris Dam. Elsie "incorporated certain external characteristics like a torpedo for stable water entry and underwater trajectory. The maximum configuration diameter was limited to a 21-inch diameter because that's what the launch tube up at Morris Dam was," recalled Frank Knemeyer, the member of the Ballistics Division assigned to the Pasadena Annex for design of the weapon's aerodynamic configuration and structure.

Elsie's ballistic flight and earth penetration tests were on the China Lake ranges, with special instrumentation developed by the Pasadena Annex incorporated in each test missile to record the dynamic motion during the ballistic flight. Each missile needed to be recovered for analysis of the flight data and for a detailed analysis of the surface impact and underground trajectory. The recovery resulted in large, deep excavations in the ground, and the Elsie team coined the word "terradynamics" to describe the analysis of dynamics for earth penetration.

Drop-test work at NOTS proceeded well, with one hair-raising near miss by a bomb shape that no doubt would have punched right through several levels of Michelson Lab if the range safety officer, James D. "Jimmy" DeSanto, had not saved the day. The plane crew had radar contact on the laboratory instead of on a target radar reflector up range. DeSanto knew the plane was out of position and expeditiously aborted the run. After the P2V launch aircraft landed and parked next to Hangar 2 at Armitage Field, the missile dropped out of the bomb bay as the engines were shut down. As a result, the instrumentation and timer were initiated.

"I had developed a technique of putting small transverse rockets in the bomb fins in order to cause oscillations at predetermined times during flight to analyze the aerodynamic characteristics, damping and so on," Knemeyer remembered. "Well, when the thing dropped out of the bomb bay, everything was energized, and Tommy Andrews, the test engineer in the plane, who was really head of structural design at Pasadena, knew that the rockets were going to go off. So he hollered for everybody to clear out of the place." Sure enough, one of the rockets in the fin fired, blowing a hole through the aircraft flap. In the ensuing pandemonium, someone pulled the deluge switch in Hangar 2, causing an indoor rain. "They had an interesting time out there," said Knemeyer. Though the missile fins were slightly bent, the Pasadena machine shop aligned the structure so precisely that the bomb did not make one revolution of roll during the entire trajectory during a later drop from a 30,000-foot altitude.

In early November 1950, the AEC asked BuOrd to develop the non-nuclear components for a more advanced version of the TX-8, and by the end of the month, the designation TX-11 was assigned to the new bomb. Since the TX-11 didn't have an underwater application, the Test Department took on the design and test work at China Lake. Knemeyer returned to the desert to run a low-profile group on the second deck of Michelson Lab. By January 1951 the Air Force decided it needed the TX-11 for use against tactical targets —bridges, fortifications, airfields, and underground installations. That July Sandia Corporation, Albuquerque, New Mexico, requested that BuOrd adapt the TX-11 design for warhead applications. The desired military characteristics of the new warhead were issued the following month.

The objective was to develop an aero- and terradynamic configuration and structure to maximize the penetration characteristic with a predictable subsurface trajectory. The Elsie team conducted tests of various aerodynamic configurations at the Caltech Guggenheim Aeronautical Laboratory wind tunnel in Pasadena. Full-scale ballistic and terradynamic shapes were tested on China Lake ranges to determine the ballistic performance and dynamic earth penetration trajectory characteristics in heterogeneous sandy soil and rocks. The station obtained a brand new F2H Banshee from McDonnell Aircraft

Corporation for a primary launch vehicle that could provide an altitude of 40,000 feet.

In each test the ground range radar controller precisely directed the pilot of the F2H on a predetermined flight path from the time the aircraft entered the area until launch at a specific point. This control was to ensure impact in a specific target area. "The process, in effect, was probably the first use of ground-control radar for remote bombing explored later by the Marines," said Knemeyer. As in the TX-8 development, transverse perturbation rockets and instrumentation were incorporated in each test vehicle, which had to be recovered to retrieve the flight data. In addition to the full-scale ballistic configuration tests, earth-penetration trajectory and soil characteristics were meticulously recorded and analyzed. These tests, probably the most comprehensive study of earth penetration at that time, provided information for critical earth entry and penetration parameters that are still applicable.[23]

In October 1951 when the Research Board discussed NOTS' support for the Elsie program, Toporeck reported that Rem (the staff branch of BuOrd's Research and Development Division that was devoted to nuclear energy applications) held the opinion that "this program is one from which the bureau will derive more in the way of information gained for dollars expended than in most of its other programs." Toporeck also offered his view. "While this work, strictly speaking, is not in this Station's mission, NOTS is probably the only place where the Bureau can place this work for some time to come," he said.[24]

The production version of the weapon, which could pierce reinforced concrete and armor plate, was renamed Mk 91 in mid-1954 and entered the fleet in 1956. During the following year, approximately 40 Mk 91 bombs were produced.[25] Details about some aspects of the Elsie work still do not appear in unclassified records, but the station's effort appears to have been significant. A letter of commendation from Bureau Chief Withington called NOTS' contributions "essential to the development of this very effective nuclear weapon system." In reminiscences on the Elsie project, Knemeyer termed the weapon probably still one of the best bombs ever built "because it was very well- and precision-made . . . [without] all the erratic ballistics that our current bombs have."[26]

Bombardment Aircraft Rocket

Another NOTS project of the nuclear age was the 30.5-Inch Bombardment Aircraft Rocket (BOAR), a large, air-launched ballistic weapon developed in 1952–1956 as one of the earliest rockets designed to carry a nuclear warhead.

The station was responsible for all non-nuclear components, with the nuclear warhead and firing components contracted to Sandia Corporation. Work on BOAR came to NOTS as part of a chain of events that began during World War II, when the heavy toll exacted by shipboard antiaircraft weapons on attacking bombers and torpedo planes exacerbated the need for standoff weapons, ones that could be fired from a considerable distance away from the target. Standoff attack became even more important when nuclear weapons, with their huge lethal radii, were developed.

In February 1951, the MLC gave BuOrd an assignment to develop an air-launched free-flight rocket capable of carrying an atomic warhead in the 24- to 25-inch-diameter range.[27] The following November Ellis presented the Research Board with a projected budget of $2 million for a two-year program. Unlike the majority of the station's projects, this one would have most of its development accomplished under contract, with limited support from the Rocket Department and the Design and Production Department. Testing was another matter. The plan was for NOTS ranges to be used for extensive ground firing and field proofing, as well as 15 drops of dummy rockets.[28]

Despite reassurances from Ellis that the new program could be accomplished with existing station resources, BOAR was unpopular with many Research Board members. Some wanted to avoid programs involving atomic warheads, preferring to focus on the conventional weapons with which NOTS had made its name. "There was also unpopularity in that less of it could be completely developed by the Station, and it was one of the first that got quite a bit of industrial input," Levering Smith explained. "I think it was the first time that NOTS had gotten involved in managing an aerospace industry project, with major AEC participation."[29]

The bureau and the NOTS Advisory Board wanted the work done, however, and by December a short schedule became shorter. The revised schedule called for delivery of 14 motors per month in addition to the originally planned 15 dummy drops.[30] In early 1952 the Joint Chiefs of Staff endorsed the MLC's decision and established a military requirement for the weapon. In March Fred Brown appointed the vigorous Stan Marcus engineer in charge of a "special project . . . for the purpose of accelerating the development of hardware for the delivery of a special warhead from tactical aircraft."[31] The MLC, which placed a high priority on BOAR, agreed in October 1952 that NOTS would have overall responsibility for the rocket and its non-nuclear components.[32]

The size of BOAR was a problem. Putting a huge rocket next to the fuselage of the host aircraft caused an interactive flow that affected the rocket's trajectory on launch so much that, according to Leroy Riggs, "If you didn't take account of it, you were going to be putting nukes in the wrong place." For the necessary aerodynamic studies, the station used a subscale "poor man's wind tunnel" near Thompson Lab. NOTS machinists made scale-model BOARs to test there. But full-scale tests were needed, and Leroy Doig, Jr., and other members of the Ballistics Division began using White Oak's wind-tunnel facilities to study the wind's flow around the bomb-laden aircraft.[33]

"Back in those days we didn't have the techniques for predicting separation of weapons from aircraft, and we did it with hand calculators, with desk calculators," said Bill Porter, a youthful ballistician on the project team. The calculations were based on data obtained in a smoke tunnel lined along one side with jets to create airflow around the test object. Photographs of the smoke flowing around the two-dimensional model of the weapon allowed contour plots to be made. In another creative way to obtain airflow data, the team covered BOAR with tufts of yarn, then subjected the weapon to air flow and measured the yarn alignment.[34] Using data from both types of tests, ballisticians could then calculate the weapon's behavior on launch.

An important part of the BOAR work involved loft bombing, which brought pilots of Air Development Squadron Five, then based at Moffett Field, to local skies where they used their sharp piloting skills and knowledge of the limits of their aircraft to develop new bombing techniques. After a low-altitude approach, the pilot would pull up sharply, tossing the bomb out at the same time, then turn steeply and fly in the other direction to get out of harm's way. Test team members reminded one another of the importance of the maneuver by evoking memories of the tragedy and near tragedies surrounding early tests of the 11.75-inch Tiny Tim rocket. After Lieutenant John M. Armitage lost his life during an August 1944 Tiny Tim test, a lanyard-operated igniter was developed to solve the separation problem by igniting the rocket at a safer distance from the launching aircraft. For BOAR the loft-bombing maneuver provided the added standoff distance needed for pilot safety.[35]


U.S. Navy photo

William B. "Bill" Porter.

Loft-bombing maneuver during BOAR launch.

Note the arc of the trajectory shown in this January 1950 artist's concept of BOAR and its launching aircraft.

The successful integration of a nuclear warhead into the rocket and of the rocket with the aircraft involved certain complications not faced with the conventional warhead. Marcus adapted the warhead and its fuze to the host aircraft so well that the bureau and the AEC enlarged his responsibility for "adaption kits" for all BuOrd special weapons. In fiscal 1955, a bureau evaluation subjected the weapon to 20 shots with 100-percent success, "a remarkable record," McLean told senior personnel that June. Describing the station as "well started in the special weapons field," he added, "I believe it is essential that such weapons be developed and be available, although I am not entirely convinced that they will ever be used."[36]

BOAR went to the fleet in 1956 and remained in service until 1963. In an era when national defense policy emphasized nuclear weaponry at the expense of conventional weapons, NOTS engineers also contributed design studies for Hopi, a higher-yield application of BOAR; Thunderbird, a long-range guided missile with a nuclear payload; and Diamondback, a big, long-range, liquid-fueled "Super Sidewinder" with a nuclear warhead option. All three programs were canceled during their early phases, but as with many other R&D efforts at China Lake, the insights gained during the work lived on.

Departure of the AEC

On 5 February 1954, the *Rocketeer* announced that a major personnel cut was planned for Salt Wells "due to a reorientation of the national defense program in certain management agencies of the government." Over the following few weeks, employees learned that production facilities at Salt Wells would be closed, with a probable effect on about 600 employees—a devastating 11 percent of the station's approximately 5,400 civilian workers. A small staff and little of the existing plant equipment would be required by the limited BuOrd programs expected to continue at Salt Wells after the AEC pullout.[37]

The information was not a surprise to station leaders, who had discussed a phase-out ever since the focus of the work had turned toward perfecting methods, tools, and techniques intended for other plants. The timing was somewhat surprising, though. New structures to accommodate new work had been built at Salt Wells as recently as 1953. Audible rumblings in the management sphere had not yet curtailed SWPP's roles as a pilot plant, process developer, and specification checker. By 1954, NOTS was providing information to Burlington and another, even larger, plant operation near Chilicothe, Ohio.[38]

Many believed that the closure was influenced by events in Washington, D.C. On 3 December 1953, AEC Chairman Lewis L. Strauss had issued a directive placing a "blank wall" between classified information and the celebrated Manhattan Project leader, Dr. J. Robert Oppenheimer. The next day Parsons had learned of this decision, and according to his wife, Martha, had been "terribly upset about it." That night he had gone to bed with a pain in his chest, and the following morning, 5 December, he had died of a massive heart attack on the examining table of Bethesda Naval Hospital.[39] With Parsons' advocacy gone, no one was left to champion the work of Salt Wells. Stating his "earnest conviction that the Salt Wells Pilot Plant would not have been closed in 1954 if Admiral Parsons had been alive," Ken Robinson pointed out that the arguments for closing the plant "all made reasonable sense concerning the advisability of closing the Salt Wells Pilot Plant; but these same arguments had been advanced many times over a period of years." The decision to close the plant occurred little more than a week after Parson's death.

Neither Captain Dave Young nor Dr. Fred Brown, the station's top leaders at that time, put forth "visible expressions of regret" at the plant's phase-out. The sole influential voice raised in favor of continuing the capability was apparently Dr. Edward Teller, who wanted to be able to order specialized research shapes to use in his work at Lawrence Livermore National Laboratory. "Dr. Teller pressed his need as urgently as he could but somewhere in the decision chain he was defeated," Robinson said.[40]

With the decision irrevocably made, the first reduction-in-force (RIF) notices came out in March 1954, with 49 employees notified that month and more notices delivered every two weeks thereafter. Some of the most highly trained engineers left for jobs at Picatinny Arsenal, Los Alamos and Lawrence Livermore Labs, Army Ordnance, and private industry. Among those departing was Longwell, who left the station in August to be admitted to the Caltech doctoral program in chemical engineering. By September, as the dust began to settle, approximately 575 employees had moved to other jobs within NOTS (including 109 employees moved from the Pasadena Annex to China Lake), with approximately 30 employees voluntarily terminating, and fewer than 20 leaving civil service involuntarily as a result of the RIF.[41] The task of closing out the AEC work was substantially completed by 30 June 1954.

With a large part of the station's work gone, NOTS faced for the first time in its existence the prospect of empty facilities. Station leaders worried about mass displacement of the highly trained chemists, ordnancemen, and munitions workers who had been so difficult to recruit and hire. The Research Board decided to move some functions from the Foothill Plant to China Lake. The Design and Production Department was divided three ways, with employees assigned to the Underwater Ordnance Department, which continued under Renzetti's leadership; to a new Engineering Department under Kelvin Booty; and to a new Technical Information Department under Robinson. The new departments established headquarters at China Lake, while UOD remained at Pasadena. With some former Pasadena Annex employees moving to China Lake, Pasadena could vacate its Thompson Lab in the former Vista Del Arroyo Hotel and consolidate all of its operations at the Foothill Plant.[42]

New Work for Salt Wells

Much of the Salt Wells plant property had been recorded on both AEC and NOTS records. The Manhattan Engineer District had financed the original construction, with additions financed by the AEC and with the station operating in effect as a contractor. As the AEC left China Lake, it sold its facilities to NOTS at comparatively small cost, leaving the station with clear ownership of the extensive SWPP assets—about 80 buildings containing an abundance of precise equipment that had been used for explosive and lightweight-warhead research, development, processing, and production work.[43]

Karsten S. "Kit" Skaar, head of the Development Division, Explosives Department, knew how to make productive use of several of the facilities being vacated.[44] He obtained equipment and personnel to develop plastic-bonded explosives (PBX), which took advantage of the light weight and structural strength of plastic for maximum explosive potential, high mechanical strength, improved chemical and thermal stability, and acceptable sensitivity. The TNT-bonded explosive loads then used in warheads imposed limitations on high-performance aircraft because of the hazards from aerodynamic heating. PBX, which blended conventional explosives with a polymeric binder, could remove those operational limitations.

Skaar and Robert Van Dolah, head of the Chemistry Division of the Research Department, visited bureau officials in Washington and obtained the necessary support. Work began in summer 1954 on a lightweight PBX warhead for the 2.0-inch Gimlet folding-fin aircraft rocket.

Chief of Naval Operations Admiral Arleigh A. Burke didn't mention NOTS when he spoke about PBX at a 1957 meeting of the American Institute of Chemical Engineers in Boston. Nevertheless, station employees who read his description of "probably the most dramatic advance in the conventional

U.S. Navy photo LO45633

Salt Wells Pilot Plant, June 1959.

explosive field," knew that China Lake could take full credit for the development he praised as an outstanding example of technology applied to the needs of the fleet.[45] At about the same time, the station released PBXN-1 for processing by a commercial plant. China Lake went on to develop many types of pressed, extruded, and cast PBXs that continue to be used in a wide variety of fleet applications.[46]

Another potential area of work at Salt Wells involved a new role in nuclear weaponry. In November 1954 personnel of the Atomic Warheads Branch, Re10, approached McLean to ask him if the station would be willing to undertake the responsibility for inspection of atomic weapons in order to advise weapon developers of specific Navy needs and advise BuOrd and OPNAV on the acceptability of the weapons under development.

McLean appointed a committee chaired by Captain Tom Walker, with Dr. Frank E. Bothwell, Ellis, and Marcus as members, to look into the possibility. Experimental Officer Walker, who had an extensive background in special weaponry, including command of the first Naval Air Detachment at Albuquerque in 1949–1952, had already brought the news that the bureau wanted NOTS to develop kits adapting Regulus I and II airframes for nuclear warheads. Marcus was planning to build on his success with BOAR adaption kits by taking on the task.[47]

The program would necessitate establishing a group of NOTS people at Kirtland Air Force Base, near Albuquerque, where they would be close to a Bureau of Ordnance Technical Liaison Office (BOTLO) to be set up in Albuquerque the following February and to the Naval Air Special Weapons Facility (NASWF), a 1952 redesignation for the detachment Walker had commanded. Since Walker's committee was already studying the possibility, the Research Board agreed "that the program will be most extensive and that the Station must be prepared to make an all-out effort to support it."

Walker visited Albuquerque that spring, returning to report the possibility that NOTS' task could be expanded to involve a determination of the vulnerability of special weapons to blast, fragments, radiation, crash impact, and fire. The Research Board declined the invitation, commenting that a heavy workload in other areas would make participation in the program unwise. "We will concentrate on a study of the Navy's needs in such a program and on methods of securing the maximum results with a minimum of tests," the board decided.

In July 1955 the bureau assigned NOTS the task of developing the acceptance program. Marcus had become head of the Rocket Development

Department's Special Weapons Division the previous November, and his employees were working on Regulus I and II adaption kits. Because this activity required security procedures not readily achievable in Michelson Lab, Marcus had moved into newly vacated office space in the Salt Wells Pilot Plant. The station subsequently lost the adaption kit project when the NOTS cost estimates failed to undercut those of Chance Vought Aircraft Company.[48] The Special Weapons Division continued at Salt Wells for about another year, during which Marcus and his employees worked on warhead designs for several proposed nuclear weapons including Diamondback and Thunderbird.

By 1957 the Special Weapons Division had become the Nuclear Weapons Evaluation Division, still assigned to the same department (by then renamed Weapons Development), but located at Kirtland Air Force Base. At this remote location, NOTS engineers evaluated several nuclear weapons, missile components and subassemblies, as well as conducting a preliminary study for a concept that involved standardizing the weight and configuration for a family of weapons of differing yields.

The work proceeded well, but a more direct connection with NASWF soon made more sense. In 1958 BuOrd redesignated the division the Naval Nuclear Ordnance Evaluation Unit and reassigned it to NASWF, thus taking NOTS out of the loop.[49]

Although this early effort to continue the station's work in support of nuclear weapons development had a satisfactory outcome, the new work it brought to the Salt Wells facilities was only temporary. However, the combination of technical facilities and remote areas of land made Salt Wells an attractive prospect for experimentation with high-energy propellants. Work that began in 1956 culminated in the establishment of a composite-propellant pilot plant capable of developing small and scaled-up rocket motors. Ray Miller recalled that when he arrived at China Lake in 1957, his job was to assist in the conversion, which involved about half of the plant facilities. "That plant is still one of the best in the industry and has resulted in propulsion systems for Sidewinder, HARM, Vertical-Launch ASROC, and many others," he said. Fuzing systems for many Navy weapons have also been developed at SWPP.[50]

Crucial Strategic Studies

The station never possessed fissionable materials, yet the NOTS influence on nuclear weaponry was profound. In particular, China Lake's revolutionary early studies changed the course of the Navy's thinking on strategic deterrence. The story of this initial NOTS involvement in Polaris illustrates the usefulness of the strong military-civilian links forged at NOTS and reinforced through productive working relationships.

America's efforts to develop a sea-launched ballistic missile began at the close of World War II, when rocket scientists from the German Army Weapons Department at Peenemünde inspired parallel postwar U.S. Army and Navy programs.[51] The Army turned to Wernher von Braun to direct a guided-missile development unit, then to direct development of the Army's rockets and ballistic missiles. But little support for sea-launched ballistic missiles existed among the Navy's leaders. As a result, the pertinent postwar Navy development programs were fragmented and small in scale. Nevertheless, at least three naval organizations sought jurisdiction over the development of long-range missiles. The Office of Naval Research wanted to pursue high-altitude rocket work at the Naval Research Laboratory; BuAer wanted to further develop Regulus I, a supersonic cruise missile to be fired from a surfaced submarine; and BuOrd sought funds for two projects, one to develop Triton as a faster alternative to Regulus and the other to design a new submarine-launched ballistic missile.

The Air Force, proceeding under the assumption that manned bombers would provide the backbone of strategic air power for the foreseeable future, proposed its Atlas intercontinental ballistic missile (ICBM) program in 1950. By 1953 several respected experts believed that an ICBM could be developed within the next few years. On the recommendation of the influential Strategic Missiles Evaluation Committee (also known as the von Neumann Committee or the "Teapot Committee"), the Air Force accelerated the pace of the Atlas development in 1954.[52]

The Navy's relatively small-scale ballistic missile programs were making little progress, partly because influential naval decision-makers opposed an emphasis on ballistic missiles. Some of these officers believed that key aspects of the technology had not proved feasible, and some feared that the new programs would be at the expense of other important Navy programs. In addition, BuAer and BuOrd quarreled over which would control the Navy's overall missile-development program. While most of BuAer's leaders wanted to pursue a diversified missile R&D program, many in BuOrd emphasized low-level air-breathing cruise missiles (actually pilotless aircraft) of the Regulus and Triton types. A few officers in BuOrd agreed with BuAer, however, that a more diversified program with a strong emphasis on ballistic missile development was needed.

In the meantime, the Soviet Union was making unexpected advances in the development of a long-range ballistic missile. As a result, the Eisenhower administration recognized the need to accelerate America's ballistic-missile programs. In 1954 President Eisenhower created a special committee, under the chairmanship of Dr. James R. Killian, Jr., a pivotal figure in the postwar scientific establishment. The Killian Committee began a thorough study of actual and prospective missile programs worldwide, with the aim of assessing the strategic significance and implications of these programs. Recommendations from the committee circulated informally among the Washington power elite in spring 1955; for the first time a powerful independent group provided support for the small group in BuAer that had been pushing for development of a sea-launched ballistic missile.

Encouraged by the Killian Committee's recommendations, BuAer Chief Rear Admiral James S. Russell told the Chief of Naval Operations in a July 1955 memo that BuAer planned to use the Operational Requirement for the Regulus missile as authorization to develop a ballistic missile that would be ready in five to seven years. The CNO reply directing discontinuance of these expanded efforts was too late. BuAer had already sent out letters inviting industrial firms and government laboratories to submit informal technical proposals for a liquid-fueled ballistic missile to be launched from a ship, preferably a submarine. Russell also used his prerogative as bureau chief to approach the Navy's civilian leaders directly, gaining approval from Secretary of the Navy Charles Thomas for the BuAer program. The Bureau of Ordnance, opposed to this assignment of responsibility to its rival bureau, urged increased support for accelerated work on its own cruise-missile concept, as well as for a program to perfect the use of NOTS-developed solid propellants in large-scale rockets.

Development of the Navy's Fleet Ballistic Missile (FBM) was a plum worth fighting for, and each development bureau argued that it had the best claim to the program. "This was the damndest fight I've ever been in in my life," said Chick Hayward, who as commander of the Naval Ordnance Laboratory was in on many of the discussions.[53] The problem was the cognizance issue that had been festering ever since guided missiles blurred the border between ordnance and aircraft. On the BuOrd side were two strong arguments: underwater and sea-launched missiles had already been defined as within the purview of the ordnance bureau; furthermore, NOTS and other BuOrd laboratories had the best applicable technical expertise. BuAer argued that it already had experience with Regulus, which was of the size envisioned for the new missile. Admiral Arleigh Burke, who became CNO in August 1955, came up with a compromise that would allow the work in both bureaus to go forward. He was too late, however, for an independent Navy program. The National Security Council had endorsed the Killian Report, which recommended an immediate focus on IRBMs, with longer-term work on guidance accuracy and reentry requirements for ICBMs. The President had forwarded the report with his approval to Secretary of Defense Wilson, and in early September 1955 Wilson gave his highest priority to ballistic missile programs, limiting their number to three Air Force programs (the Atlas ICBM, the backup Titan ICBM, and the Thor land-based IRBM) and a fourth program that would involve the Navy in developing a sea-based support system for the Army's Jupiter.

In November 1955 the Secretary of the Navy established the Special Projects Office (SPO) as a separate office outside of the bureau structure to solve problems associated with ship launch of Jupiter-S, a huge sea-based solid-propellant missile to be designed by Aerojet-General Corporation and Lockheed Missile and Space Division and proposed as a joint Army and Navy program. The small, flexible SPO organization would soon take Jupiter-S in a new direction.[54] Rear Admiral William F. "Red" Raborn, Jr., reported for duty as head of SPO on 28 November 1955. Already on board was a former NOTS leader, Captain William A. Hasler, who had been in charge of the Pasadena Annex in 1947–1952. The work of SPO was so important to the Navy that Burke issued an order that became famous as "Red Raborn's hunting license," extraordinary authority for Raborn to select the cream of the Navy's crop for

U.S. Navy photo USN 710496, courtesy Naval Historical Center

Rear Admiral William F. Rayborn (left) and Admiral Arleigh A. Burke examining a cutaway model of the ballistic missile submarine *George Washington* (SSBN-598) in July 1959.

his project.[55] With hunting license in hand, Raborn reached out for another prominent NOTS alumnus, Levering Smith, who reported for duty as head of SPO's Propulsion Branch in late March 1956.

Soon after Smith arrived, he assigned NOTS its first work in support of Jupiter-S: small-scale rocket feasibility tests to explore a capsule concept as a potential solution to the difficulties of underwater launching. In October 1956 NOTS conducted its first small-scale flight test to check separation techniques. Within the following week the station successfully conducted three underwater capsule launching tests. But by then NOTS was involved in other work of far more importance to the ultimate development of the Polaris missile.

When Smith came into the project, Raborn and his growing team were struggling with the assignment to adapt Jupiter-S for submarine launch. The missile's huge size, necessitated by what were then the limits of solid-propellant technology, had skeptical submariners predicting launching mishaps and accidents underway, as well as questioning whether a submarine large enough to carry the monstrous missile was feasible. Designed around the same reentry body as the liquid-fueled Jupiter, the planned Jupiter-S would have a 43-foot length, with a diameter of 10.5 feet, would weigh 168,000 pounds, and would incorporate a two-stage cluster of seven solid-propellant motors. A virtually impossible schedule called for testing the missile in 1958, deploying it on board a freighter in 1960, test-launching it from a submarine in 1963, and deploying it from a missile-carrying submarine in 1965. Smith recalled that he began overseeing development of "a very inefficient cluster of solid-propellant motors" that would use the guidance and warhead re-entry vehicle being developed for Jupiter-S. While work went forward on submarine modifications to allow transport and launch of four of the massive missiles, he began looking for a more elegant solution. He asked a team of NOTS Weapons Planning Group (Code 12) analysts under Bothwell's leadership to advise him on the characteristics of an improved missile to be used in place of Jupiter-S on the newly enlarged submarines. This study became known as Project Mercury.[56]

As a former China Laker, Smith knew that Bothwell and Code 12 possessed the analytical skills necessary to coordinate the work.[57] Bothwell assigned Don Witcher the task of taking a critical look at the Jupiter-S components. Witcher soon concluded that modifying Jupiter-S was not a satisfactory option. His results, however, led to the possibility that a 30,000-pound missile powered by solid propellant could be developed within a reasonable schedule and that this new missile would also be superior in other respects to Jupiter-S. After a more intensive study, Witcher and his Project Mercury team of seven or eight Code

12 analysts recommended that SPO redesign every part of Jupiter-S, including the reentry vehicle and the guidance package, with the intent of reducing weight wherever possible. The team, which called on related resources all over NOTS in the course of the study, took a far-sighted approach, according to member Frank Knemeyer. "Look into the future, see what technology is going to give you instead of just take just what you have today," he said. "Don't build a new missile with almost obsolescent components."[58]

The group had unrestricted access to the resources of Lawrence Livermore Laboratory, and in a study of the laboratory's applicable literature, Knemeyer found a detailed Rand Corporation review of reentry heat shields and materials. By studying nuclear warhead designs, he also discovered that the warhead case structure was composed of one of the materials discussed in the Rand report. He concluded that by integrating the nuclear and missile technology, the weight of a separate heat shield could essentially be eliminated, thus permitting a significant reduction in missile size and weight—as much as 60 to 80 pounds per pound of payload weight, depending on the desired ballistic range. At the NOTS Ballistic Firing Range, Knemeyer conducted a flight test of a reentry configuration compatible with a new warhead concept under development at Livermore.

Raborn and Smith were impressed with the Project Mercury recommendations, and after SPO obtained the capability to flight-test a full-scale model, the project shifted over to the more efficient integral reentry warhead proposed by Knemeyer.[59] Both Smith and Raborn believed that the Project Mercury recommendations were feasible but feared that a radical redesign might jettison their entire program, given the highly political process through which the program had achieved its funding. For that reason, they decided to continue with plans already in place to test Jupiter-S on a surface ship in 1958 and to deploy it on a submarine in 1965.

Smith then asked Bothwell to proceed with a new study, Project Atlantis. China Lakers Dr. Glover S. "Dud" Colladay and David S. "Dave" Bloom conducted the study, which estimated the damage U.S. ballistic missiles would need to inflict to keep an enemy from striking back in the event of a nuclear war. Central to Colladay's and Bloom's study was the concept of deterrence rather than a counterforce posture. The idea, still central to U.S. nuclear policy, was to avoid war by convincing the enemy that an attack would result in disastrous consequences. With little directly pertinent data available, the two Code 12 analysts based their conclusions on the impact severe natural disasters had on cities. After developing a mathematical model for determining damage levels, they checked the model against damage sustained during the Hiroshima and Nagasaki attacks. "These calculations were in surprisingly close agreement," Knemeyer said. "Further, these results indicated the significant value of employing low-yield warheads."

Colladay and Bloom then conducted the most comprehensive analysis yet undertaken of potential nuclear attacks on Soviet cities. After examining the physical characteristics of more than 300 cities in great detail, they estimated the nuclear warhead yield necessary to kill one third and to injure one third of the people, a damage level they had previously determined would cause a maximum level of disruption. They estimated that 25 functioning one-megaton warheads against as many cities would essentially wipe out Soviet governmental control. This number was far smaller than those postulated by previous studies. Colladay and Bloom also insisted that the IRBM itself should be much smaller than the size recommended by previous studies. Both of these conclusions were controversial, with military authorities generally determined to stick with larger warheads.[60]

The Nobska Study

In late 1955 CNO Burke asked the Committee on Undersea Warfare of the National Academy of Science to study how advanced technology could be used to counter the "growing Russian submarine menace." As a result, Woods Hole Oceanographic Institution in Massachusetts in summer 1956 hosted an intensive study, "The Implications of Advanced Design on Undersea Warfare," known as Project Nobska, named for Nobska Point about a mile away from Woods Hole. The first of several summer studies the Navy sponsored under contract with the National Academy, Project Nobska had 60 participants, fully a third of them from naval staffs and laboratories. Members decided that the study should encompass strategic uses of the ocean as well as conventional antisubmarine warfare. For this reason participation from nuclear-weapon and propulsion experts—including Bothwell—was solicited.

After encountering considerable initial resistance, Bothwell convinced the other participants in the Panel on the Strategic Use of the Undersea to include submarine-launched ballistic missiles in the study, with warhead weight and yield estimates to be based on those made by NOTS and by Dr. John S. Foster, then at Lawrence Livermore Laboratory. Bothwell had help from Teller, who visited in August to ask why the group was designing a 1965 weapon with 1958 technology. The panel eventually concluded that a ballistic missile of the 1,500-mile range would need to weigh 25,000 to 30,000 pounds as opposed to the previously estimated 150,000 pounds and that a fleet of submarines, each armed with the new lightweight missile, would be a more effective strategic deterrent than Jupiter-S. That was an amazing assertion to some of the participants, but Teller won the day by pointing to trends in warhead technology that showed major weight reductions in each generation of warheads.

The panel also prepared extrapolations of the major subsystems a new lighter-weight missile could use. Each improved component, looked at separately, made little difference to the overall weapon system performance, but a lot of little improvements added up to what promised to be a much more effective system. These calculations provided the basis for the panel's recommendation that the Navy build a solid-fueled ballistic missile weighing 8 to 15 tons, having a range of from 1,000 to 1,500 miles, and carrying a relatively low-yield warhead.

Not all Nobska participants agreed with the panel's recommendation. But when Burke arrived for a preliminary briefing in late summer, Smith recalled, "They had set aside a good part of the afternoon for questions, and Burke spent the whole afternoon discussing that and nothing about all the rest of the study."[61]

On Labor Day weekend 1956, Bothwell and Witcher met with Raborn, Smith, Dr. L.T.E. Thompson, and others at SPO in Washington, D.C. Raborn, Smith, and Thompson (hired by Smith as a consultant) immediately adopted the idea of a smaller missile. In October 1956 when Burke endorsed the Nobska group's final report, in particular the chapter written by Bothwell and Witcher, he offered the first official support for the position that a nuclear device small enough to be launched from a submarine could be created. Raborn convinced the AEC to officially support the study's estimate, then pressed for cancellation of Jupiter-S in favor of the new concept. Secretary of the Navy Thomas and Secretary of Defense Wilson agreed with Burke that, given the promise of the new concept, a divorce of Army and Navy efforts made sense. On 8 December 1956, the Secretary of Defense authorized the Navy to delete Jupiter-S from its IRBM program. The Joint Army-Navy Ballistic Missiles Committee was abolished, and the Navy was given the green light to proceed with a new lighter-weight ballistic missile. Raborn named it Polaris after the North Star, sailors' main navigation guide for centuries.[62]

In January 1957 SPO established a steering committee to study all aspects of the Polaris system design, with a recommendation on optimum size due that April. The committee recommended a system somewhat more conservative than that proposed by the China Lake analysts, but still light enough at around

30,000 pounds to increase the feasibility of meeting the schedule with a missile system and submarine configuration. Central to the concept was the 600-pound, one-megaton warhead Polaris would carry.

With reasonable parameters, excellent system management, and a virtually unlimited checkbook, SPO was able to beat the initial schedule for Jupiter-S submarine deployment by a full four years. On 20 July 1960, with Raborn on board to enjoy the success, *George Washington*, the first sub of its class, submerged and successfully launched its first Polaris. On the way to that success, China Lake made other contributions to Polaris, notably in launching technology and underwater propulsion systems. The initial analytical efforts of the Weapons Planning Group, however, deserve a special place in China Lake's history. These studies later influenced the design and hardware development of Polaris and of its successors, Poseidon and Trident. More importantly they had a profound effect on the nation's strategic deterrence policies.[63]

As Phil G. Arnold put it, "China Lake's primary resource was brains."[64] And those brains often operated "outside the box" to meet the new challenges of the nuclear age.

13

Expanding Torpedo and Undersea Research Programs

As the emphasis at China Lake shifted in response to the evolving needs of the fleet, the Pasadena Annex also adjusted to new requirements. A big change occurred in 1952 when NOTS was assigned technical direction of the Navy's air-launched torpedoes. New sea test ranges off the Southern California coast soon followed. Work also began on new torpedo concepts and new antisubmarine weapons.

Rethinking the Torpedo Program

New work arrived at the Pasadena Annex in the early 1950s as a direct result of BuOrd's postwar torpedo reassessment. Widespread torpedo failures in combat had eroded fleet confidence in these undersea missiles. In addition, the ever-increasing launch speeds of both aircraft and submarines required improved torpedo technology. The postwar political climate, however, seemed to rule out funding for these improvements. "In those days everyone was hypnotized by the aircraft and atom [bomb] threats almost to the exclusion of all else," recalled Schoeffel, who was then deputy chief of BuOrd. "As a result any attempt to improve submarine weapons, particularly torpedoes, was met by the derisive question, 'And what targets will you use this against?'"[1] Bureau leaders decided that the best approach would be to come up with a plan for a pared-down torpedo program that could operate within the funding already allocated. Dr. Gaylord P. Harnwell of the University of California led a committee of scientists who developed the plan and published it in a document termed the Harnwell Report.[2]

The report's most significant recommendation was that the entire torpedo program be supervised by one permanent laboratory under bureau cognizance. Since four laboratories—NOTS, NOL, Pennsylvania State University's Ordnance Research Laboratory (ORL), and the Naval Underwater Ordnance Station (NUOS), Newport, Rhode Island—worked on torpedoes or torpedo components, the recommendation was controversial. To minimize the upset, Harnwell and his colleagues suggested that the four laboratories agree on an implementation plan to consolidate the torpedo program. Thus was born the Torpedo Planning Advisory Committee (TORPAC).

BuOrd established TORPAC in May 1951, with members representing the bureau's Underwater Ordnance Branch (Re6), as well as the four affected laboratories. TORPAC members tackled their assignment with enthusiasm, meeting every five weeks in Washington for two- to three-day continuous sessions. Renzetti, the fiery head of the Underwater Ordnance Department, represented NOTS.[3] The TORPAC members agreed to begin deliberations by deciding which ongoing torpedo programs should continue and at what pace. The more difficult recommendations on which organization(s) should work on these programs would be made in a second phase of deliberations. This procedure seemed to work well, and Renzetti sent home reports that sessions were harmonious and useful.[4] In November he brought word back to China Lake that as a result of the TORPAC meetings, "decisions recently reached by the bureau are contrary to those reached by the Harnwell Group, viz: that the responsibility for the Torpedo Program will not be delegated to a single laboratory."[5]

The participants eventually reached consensus on a distribution of responsibility, and in May 1952 BuOrd agreed with the TORPAC findings. Under the new policy Newport would have technical direction of certain surface-launched and submarine-launched torpedoes; Penn State would continue direction of the torpedoes already under ORL cognizance; and NOTS would be assigned technical direction of the Navy's air-launched torpedoes, including Mk 27, Mk 32, Mk 41, Mk 42, and the Mk 24 passive-acoustic homing mine. The station would be expected to coordinate and direct the programs it was assigned.[6] The Pasadena Annex had gotten a jump-start on its new responsibilities and was already working on two complete torpedoes, Mk 32 and Mk 42. The official acknowledgment of the annex's expanded responsibilities underlined the need for more physical assets.

Some UOD employees were unhappy with the new policy, which they saw as concentrating on hardware at the expense of research. Others complained that antisubmarine weapons were being emphasized at the expense of "pro-submarine" work on submarine-launched torpedoes. Doubters in Pasadena pointed out that NOTS ought to focus its efforts where it already had expertise: in acoustic reverberation, water-entry ballistics, and stability and control; as well as in torpedo components including propellants, turbines, batteries, motors, and pumpjets.[7] Employees of the Design and Production Department also worried about a possible reduction in work, a seemingly paradoxical concern brought about by what D&P labeled "the current trend towards accomplishing work off the station by means of 'package' engineering and production contracts."[8] In the face of these concerns, Pasadena leaders expressed confidence that the station's underwater work could expand to encompass the new responsibilities. "We were a mature organization and ready to move out," said one of those leaders, D. A. "Bud" Kunz, a Caltech graduate with long experience in design engineering at the Pasadena Annex.[9]

After considerable discussion, the Research Board agreed to accommodate the new torpedo responsibilities, and the station formally accepted them on 10 July 1952.[10] Central to this decision was the fact that NOTS had begun useful improvements to its underwater testing facilities in 1949, when water-entry studies called for a good launching site for testing high-velocity air-to-water and underwater rockets. The facilities at Morris Dam were too small to accommodate longer-range torpedoes, and neighboring homeowners complained that the tests represented a safety hazard.

The Research Board had debated the merits of both Walker Lake and Salton Sea as potential underwater test sites, but had expressed the most interest in Haiwee Reservoir, located in Rose Valley 40 miles north of the China Lake community. The reservoir, a long blue gash in the dusty desert landscape, had been a temporary site for NOTS water-entry tests during World War II. Now it was part of the water storage and supply system of the Los Angeles Department of Water and Power, which could be expected to oppose the possible contamination of its precious water supplies.[11]

Pasadena Annex leaders suggested an alternative: the waters around 21-mile-long San Clemente Island, the southernmost of California's Channel Islands. The Navy arrived in 1934 and established an auxiliary air station there during World War II. By 1949, when NOTS began using the island, only four maintenance men lived there. The main inhabitants were wild goats that roamed the ridges and canyons, finding shelter in caves formed by the cooling lava of prehistoric ages. Other mammals were a few gray foxes, wild boars, and wild cats, descendants of the house tabbies of early sheep ranchers.[12] The island's most desirable feature from an underwater-test standpoint was a rugged eastern shore, which rose abruptly in a 2,000-foot-high escarpment sheltering the crystalline water below from fog and prevailing winds.

In an October 1949 Research Board meeting, Fred Brown, then associate head of UOD, argued persuasively for the island as a site for torpedo testing.

Wilson Cove, San Clemente Island.

He pointed out that San Clemente Island had deeper, clearer water and less hazardous conditions than did Haiwee Reservoir. A study committee agreed, and in January 1950 the Research Board endorsed the committee's recommendation for the island location.[13] After the Commandant Eleventh Naval District gave permission for NOTS to use San Clemente Island, UOD and the Rockets and Explosives Department jointly established an air-to-water firing range on the island in October 1950. The station's underwater test people were delighted with the many good sites the eastern escarpment offered for launchers and instrumentation. Photographers, who had found good documentation nearly impossible in the murky depths at Morris Dam, would be able to document underwater tests as never before. The island's barren terrain was also desirable because its relative lack of vegetation would reduce fire hazards from launching operations and "wild" rocket impacts. The station built concrete launching pads along the steep coast at elevations allowing water-entry angles from 5 to 25 degrees. Portable launching rails on iron frames were constructed so that they could be trucked from one launching pad to another.

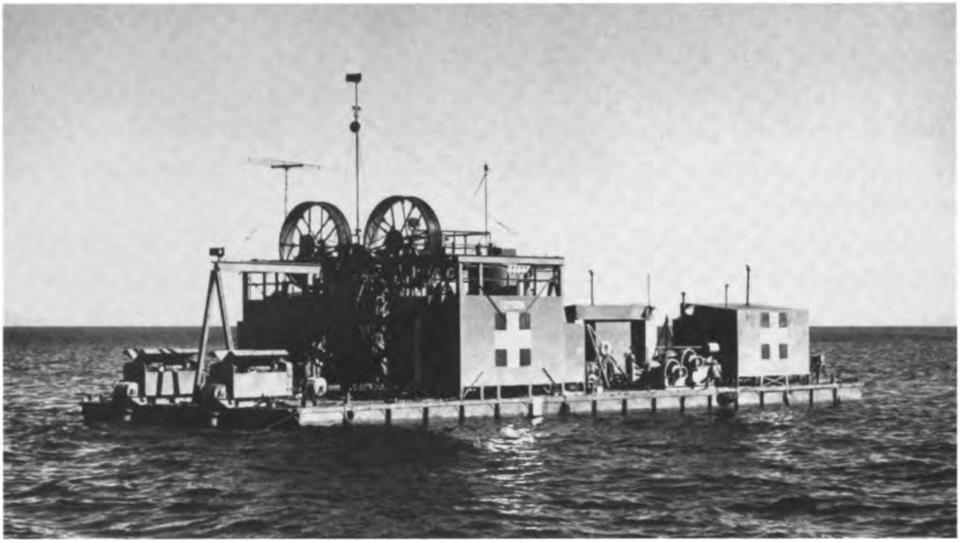
At first NOTS used the island sporadically. A test crew typically took the first half of a long Monday to travel from the Foothill Plant to the San Diego dock and to the island aboard a yard freighter. Regardless of test duration, the crew had to stay on the island until noon the following Friday, when the yard freighter made its return trip to the mainland. This delay was a welcome one for some crew members, since the surrounding waters were a fisherman's paradise. The test crews spent many pleasant off-hours fishing and hunting abalone at low tide. One crew member dropped his line casually off the end of the NOTS Pier and caught a 48-pound white sea bass. But the leisurely schedule could not continue. A 1950 study of the situation commented that "the current operation on the island, although on a shoe-string basis, is an expensive one."[14]

Major changes began in 1951, when the station turned over responsibility for maintenance of the Wilson Cove area to the Air Force, which built barracks and a mess hall for approximately 200 men of the 670th Aircraft Control and Warning Squadron and began running a radar station on the island.[15] In 1952 NOTS built new facilities, including a pier to extend several hundred feet offshore in the test area, an underwater launcher rail mounted on the seaward end of the pier, an elaborate camera barge, and a diesel-powered launching barge. Air-to-water rocket launchers were added along the shore, and an air-to-water cableway was planned for captive launchings of missiles, from small rockets to full-scale torpedoes.[16] The station also installed an Underwater Rocket Range, an East Shore Range for tests of shore- and underwater-launched missiles, and a Torpedo Warshot Range for exploder and warhead evaluation for all Navy torpedoes. In 1953 the Naval Amphibious Base, Coronado, took over administration of the island. The station contracted for air service, which made work on the island more efficient, if less fun.[17]

NOTS' Pint-Sized Navy

In addition to new sea ranges and launching facilities, the station acquired ocean-going vessels to support the increasing variety and number of underwater tests. UOD folks lashed together a stable launch platform, the first modest member of the "NOTS Fleet," from a large stockpile of pontoons left over from construction of the Variable-Angle Launcher.[18] An October 29, 1951, launching ceremony in which the new vessel, officially termed the Deep-Depth Launching and Test Facility, slid down the ways in a spray of champagne did little to glamorize what one employee of the Pasadena Annex described as "a bunch of pontoons with some shacks on it . . . powered by big outboard engines on the back end of it to push it along."[19]

The unprepossessing craft, christened Trygon after a bottom-dwelling species of ray, had a displacement of approximately 500 tons and offered a frequent target for merriment as she wallowed through the waves—but she did the job. A well in the middle of the barge allowed a stable platform to be lowered as much as 600 feet into the sea. Anchors and winches for accurate


U.S. Navy photo LHL-P A 1018, courtesy Jim Campbell

Trygon deep-depth launching and test facility.

positioning were mounted on the deck, and four underwater cameras could document the first 60 feet of a submerged launching. Other equipment allowed communication with the shore and accurate measurement of the azimuth and elevation angle of the weapon at launching.[20]

Trygon proved a useful platform for underwater launchings and measurements of noise and vibration. Scientists also used the barge for research designed to decipher the mysteries of underwater sound. This UOD program, entitled "Acoustics of the Ocean Medium," looked at reverberation and reflection in the sonic and the lower ultrasonic frequency ranges, including the frequencies at which torpedo homing systems normally operate. The study, under Dr. Halley Wolfe, head of the Guidance Branch at Pasadena Annex, involved sending carefully controlled acoustic signals into the water, then receiving and recording the resulting reverberations for later reproduction and analysis. Reverberation in the ocean came from suspended particles, trapped air bubbles, marine organisms, surface waves, or bottom roughness—all factors the experimenter could not modify. Trygon and an associated heavy frame that could be lowered into the sea provided the stability to ensure that at least the experimenter's signals were controlled.[21]

While work began on facilities for San Clemente Island and the NOTS Fleet, the station also came up with shore-based docks and shops. After a survey of all prospective locations within 300 miles of Pasadena, NOTS selected Reeves Field, a deactivated Naval Air Station in Long Beach, as home port for the new

Long Beach Test Range. Commander Naval Station Long Beach gave NOTS permission to modify Reeves Field facilities to accomplish assembly, storage, docking, and repair, as well as to conduct air drops and surface firings in 476 square miles of sea off the Southern California coast.[22] Reeves Field and the ocean surrounding it suited the station's purposes well. One advantage was the field's location next-door to the Long Beach Naval Shipyard and 30 miles south of the Pasadena Annex. Furthermore, because the offshore Channel Islands and the high promontory (Point Fermin) north of the sea ranges sheltered the operating area and because the prevailing climate was mild, test conductors could rely on good weather at least 80 percent of the time.

The new NOTS Fleet grew apace. "Today, the Annex has at its disposal a pint-sized Navy—18 sailors, 12 civilians, 2 officers, 3 LCM's [Landing Craft, Mechanized], 2 AVR's [Aircraft Rescue Vessels], a part-time submarine (one week out of a month), and various aircraft," according to a September 1953 issue of the *Rocketeer*. "With testing of torpedoes going on daily in the 8 by 9 mile area off Long Beach, even this force is inadequate."[23]

Classy New Quarters

The expanded torpedo responsibilities meant growth for the entire Pasadena Annex. Pasadena laboratories and offices were overcrowded, with the 430 employees who transferred to NOTS from the General Tire and Rubber organization in 1948 increasing to more than 1,300 by 1951. Then the California Department of Transportation announced that the route for the new 210 freeway would go through a corner of Foothill Plant property. The planned freeway wouldn't take up much of the Navy's space, but construction activities were bound to be disruptive.[24]

The station's search for suitable quarters for displaced Foothill Plant workers led to the Vista Del Arroyo Hotel, a spacious seven-story building on 125 South Grand Avenue, overlooking West Pasadena's Colorado Street bridge. The quaint hotel had inviting tile roofs, a gardenlike setting, about 159,000 square feet of floor space, and more closets and bathrooms than any work group could reasonably use. In 1942 the Veterans Administration had used the building, which had not been a hotel for many years, to house McCornack General Hospital. With the end of World War II, the hospital closed, and the building stood vacant until 1951, when the Army Engineers, the building's custodians, granted the Navy rent-free tenancy with the proviso that NOTS would vacate the building with as little as 30 days' notice. The Underwater Ordnance Department began moving into the hotel that August.[25]

The NOTS tenants decided their new quarters should have a more suitable name. From time to time Pasadena employees had grumbled about application of the term "annex"; the argument was that "laboratory" would sound less subservient to the China Lake part of NOTS. On October 18, 1951, the Vista Del Arroyo was renamed Thompson Laboratory in honor of the station's first technical director, who had officially left NOTS only four days earlier. This name choice was popular among Pasadena employees, first because it honored Thompson's contribution to NOTS, but also because those who objected to the Pasadena Annex designation could refer to the Pasadena operation as Thompson Laboratory.[26]

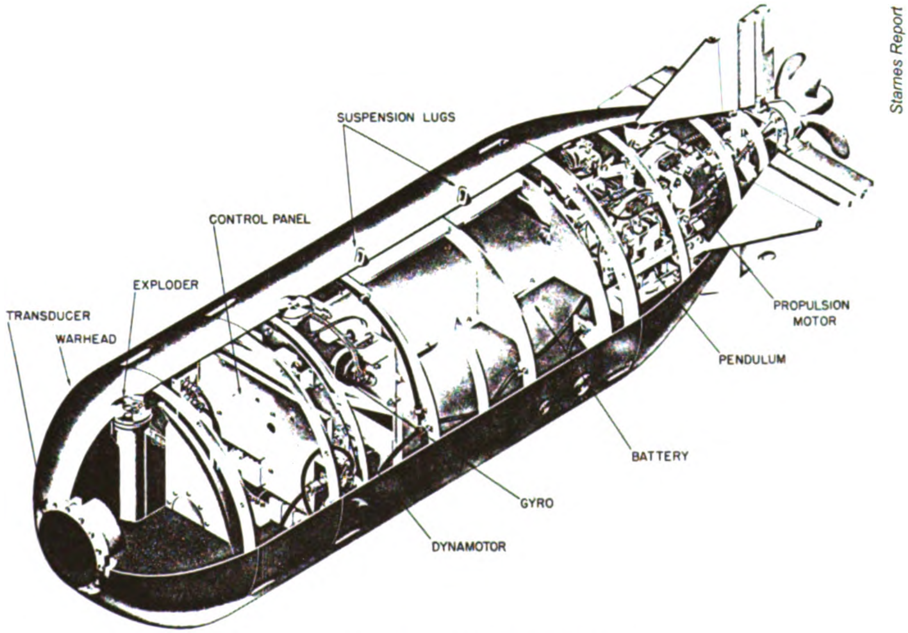
The old hotel provided a temporary solution to UOD's space problems, but annex facilities were still widely dispersed. Finding that dispersion "unsatisfactory to a serious degree," a 1952 Inspector General audit "seriously questioned . . . the ability of any one individual, civilian or military, to coordinate this complex organization." Noting the station's plan to consolidate most of the Pasadena activities at the Foothill Plant, the audit team urged that BuOrd instead develop a more expansive plan "efficient, physically integrated facilities."[27] That year the station vacated the Green Street facility, consolidating Pasadena Annex employees into Thompson Lab and the Foothill Plant. The employees used the old hotel until 1954, when Pasadena lost people and work as a result of the reduction-in-force following AEC withdrawal from Salt Wells.

New Torpedo Concepts

The Mk 32, the first complete torpedo assigned to the Pasadena Annex, had seen limited use during World War II, but had been cancelled with the end of hostilities. In early 1951, in response to the needs of the Korean conflict, BuOrd took the weapon out of mothballs and assigned Pasadena responsibility for technical design cognizance during production, proofing activities, and training.[28] Before production of the weapon could start, UOD torpedo experts worked on the redesign, primarily to improve producibility and reliability and to replace obsolete components. But their new components added weight that sharply reduced the weapon's climbing ability. Weight and buoyancy studies showed that installation of a 10-inch extension between the shell cylinder and the nose section would solve the problem. This version of the weapon became the Mk 32 Mod 1, notable because it used standardized parts found in other torpedoes. Philco Corporation rolled the first five models of Mod 1 off the production line in April 1952.

Even as the annex began testing these prototypes, the bureau proposed modifying the weapon to change from a lead-acid battery to a lighter-weight zinc-silver battery. That lighter weight allowed the extension to be removed. In August Mod 2 prototypes incorporating these design changes were tested at the new Long Beach Test Range. After tests indicated no significant difference between Mod 1 and Mod 2, both were scheduled for launching against submarine targets. By December the annex completed 450 test runs for Mod 1 and 250 runs for Mod 2, and the station recommended putting Mod 2 into production and canceling Mod 1. BuOrd concurred and directed Philco to convert into Mod 2 the 980 Mod 1 units it had manufactured. After a favorable evaluation by the Operational Development and Evaluation Force (OPDEVFOR), the bureau extended production by another 850 units and ordered the Naval Ordnance Plant in Forest Park, Illinois, to tool up for production.

In February 1953 the first Mk 32s rolled off the assembly line for final fleet acceptance. Shipment of these torpedoes culminated a two-year push by a task force of consultants, engineers, mechanics, draftsmen, support staff, and naval personnel. The UOD contribution had included the torpedo's first operational manual, as well as engineering for production, technical evaluation, and proofing.[29]

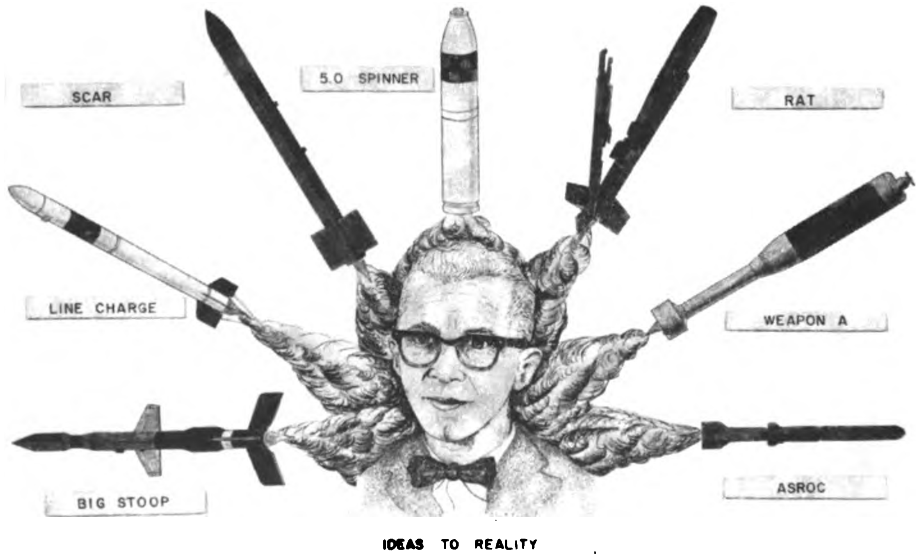


Cutaway view, Torpedo Mk 32 Mod 1.

In 1950 BuOrd assigned Pasadena the design of the Mk 42 torpedo afterbody, including power plant and control system. Other organizations involved in designing Mk 42 components included ORL, NUOS, and NOL. In fall 1951 the bureau transferred technical direction to NOTS. Annex designers effected considerable weight savings by using innovative aluminum components throughout, including even the engine and the turbine case. But the weapon, which promised only marginal improvements over existing torpedoes, didn't survive the TORPAC review.[30]

While Pasadena torpedo engineers honed their skills on the classic Mk 32 and Mk 42 torpedo design, the station pursued a new type of weapon—neither rocket nor torpedo but a cross between the two—the Rocket-Assisted Torpedo (RAT), which gained its acronym in recognition that it could neither swim nor fly all the way to its submarine target. A project that was neither all fish nor all bird must be a beast, said the weapon's designers.[31]

Like other station projects of the era, RAT was a product of a "just get it done" attitude. One at BuOrd who shared that attitude was Albert Wertheimer, Director of Ordnance Sciences (ReO). Wertheimer was "the best combination of a ballistician and a politician to be found in the old Bureau of Ordnance," according to Barney Smith, then head of the NOTS Rocket Department's Anti-Submarine Branch. Agreeing that a new torpedo paradigm was needed to exploit improvements in sonar detection devices, Wertheimer and Smith



Courtesy Barney Smith

Drawing of Bernard "Barney" Smith, presented to him as he left NOTS in 1959.

arrived at the idea that a destroyer could use a rocket booster to hurl a torpedo to the vicinity of a far-off enemy submarine, thus increasing the submarine-kill zone of the destroyer by many square miles and allowing the ship to stay out of the retaliatory range of the enemy sub. Wertheimer discussed this possibility with his peers in the bureau, but encountered reactions that ranged from skepticism to indifference.

In early May 1950 Smith, Wertheimer, and his able assistant Harry Silk agreed that NOTS was the best place to develop the thrown-torpedo idea. Wertheimer sent NOTS a task assignment, "Improvement of Ahead-Thrown Weapons," a title prudently chosen to fit within his area of cognizance, which encompassed rockets, but not torpedoes.[32] The document called for a rocket motor to project the passive-acoustic Mine Mk 24 up to 3,000 yards; for the motor, supporting structure, and air-flight stabilizer to be jettisoned at or before water entry; and for the mine to enter the water at a maximum velocity of 300 feet per second.

Smith and members of the Rocket Development Department's Anti-Submarine Branch, notably Jim Bartling and Jerry Saholt, began working on full-scale demonstrations of a test vehicle building on Weapon A techniques and incorporating a dummy Mk 24 mine, a solid-fuel motor, a finned structure to join the rocket and mine, a modified mechanical fuze for separating the structure from the mine, a parapack for stabilizing and decelerating the mine in flight, and a release mechanism for disengaging the parachute from the mine at water entry. Eight successful test-vehicle firings on China Lake's Charlie Range between July 1952 and June 1953 established the test vehicle's feasibility.

Impressed by the tests, TORPAC members asked during a March 1953 meeting at NOTS whether Mk 24 should be replaced by a Mk 43 homing antisubmarine torpedo, which would provide more "bang for the buck." The Mk 43, the first lightweight, antisubmarine torpedo capable of being launched by helicopters, fixed-wing aircraft, and surface ships, was under the design cognizance of the General Electric Company and was being jointly developed by the Pasadena Annex and Brush Development Company of Cleveland, Ohio. The relatively fragile Mk 43 needed protection as it hit the water.

Torpedo specialists in Pasadena had already begun testing a redesigned version of the Mk 43 featuring a protective air-brake clamshell to be jettisoned on water entry. The UOD team also began visiting G.E. plants in Syracuse and Schenectady, New York, and Pittsfield, Massachusetts, as well as naval torpedo-testing facilities at Key West, Florida, in preparation for closer working relationships with G.E.

A crew of NOTS engineers, technicians, mathematicians, and analysts participated in evaluation runs at the Naval Ordnance Unit, Key West, in January through March 1953. After 56 runs against a submarine, the NOTS crew evaluated the test data, delivering a preliminary report to BuOrd on 16 February. Although lacking the specific answers and clear-cut guidelines the bureau had hoped for, the report did describe several Mk 43 Mod 0 deficiencies and recommend relatively easy improvements.[33]

In April NOTS and G.E. assumed joint technical direction of the torpedo's design and development. Six drops, conducted at Long Beach beginning in June, demonstrated the promise of the clamshell approach, as well as the need for a strengthened torpedo nose, and convinced BuOrd that Mk 43 Mod 0 was the most promising payload for RAT. A study conducted by the station's Central Evaluation Group reinforced the promise of a rocket-projected torpedo as an effective way to take advantage of the improved submarine-detection capability of new shipboard sonar equipment.[34]

In 1954 Captain Eli Reich of BuOrd introduced Phase B RAT and increased the range requirement from 3,000 yards to 5,000 yards. Undeterred, Barney Smith and his team termed the project Super RAT and incorporated an improved version of Mk 43, plus several structural changes.[35]

One of RAT's biggest problems was the damage its delicate internal components could suffer as its head entered the water—and the longer the range, the bigger the challenge. UOD torpedo designers had spent years working on various types of frangible nose caps designed to reduce the entry shock by streamlining the torpedo's blunt nose. The Mk 13 torpedo had some success with a plywood drag ring, called a "pickle barrel," but for RAT this device offered insufficient protection. A British cast-aluminum protector, referred to as a "Jane Russell" in honor of the amply endowed movie star, proved unsuitable when the solid-metal device damaged torpedo fins, rudders, and propeller. A hemispherical cap made of Styrofoam also provided inadequate protection.

The UOD team finally selected a nose cap made of Strux, a cellular cellulose acetate with a crushing strength six times that of the Styrofoam cap. After air drops on the Long Beach range and tests on the Sling Shot facility at Morris Dam, a hemispherical Strux nose cap was designed that incorporated an axial hole through its center. As the nose slammed into the ocean, water entered the hole and shattered the cap, which absorbed much of the entry shock. The new design tested so well that a station report called the cap "a major contribution to the field of aircraft torpedoes" that made possible "no upper limit to release, from the structural damage standpoint, for a parachute stabilized torpedo."[36]

RAT's developers were proud of the cost savings and improvements in effectiveness resulting from careful engineering for production. In the airframe, for example, Harry Humason and other production specialists eliminated 164 rivets by pouring plastic foam into the fin shell, thus replacing an internal aluminum framework and reducing the cost by 50 percent and the weight by 25 percent. Not content with this improvement, the group later replaced the poured plastic with a Styrofoam wedge cemented into the fin, thus making possible a range increase of 600 feet.[37]

As Super RAT was ready to enter the fleet, bureau authorities decided to increase the range again, this time to 10,000 yards. The story behind that decision started in December 1954 when Captain (later Vice Admiral) Edwin B. Hooper became assistant chief for research (Re). During his previous assignment as the BuOrd assistant director for nuclear applications (Rem), he had asked NOL to review the bureau's projects with the potential for tactical nuclear application. In the resulting Aliex study, published in March 1953, NOL had made several useful recommendations, among them that RAT be superseded by a nuclear depth charge launched by a JATO (jet-assisted takeoff) rocket atop a Talos booster stage.

When Hooper became Re, he remembered the depth-charge concept as having been especially promising. He decided to authorize development of the concept as a replacement for RAT. In the first few weeks of his new assignment, Hooper and his staff put together several proposals, including one for a rocket-thrown depth charge. The initial idea was that a rocket motor would hurl a nuclear depth-bomb payload through the air toward the target, the airframe would separate and fall away, and the bomb would plunge to a preset depth and explode. OPNAV soon approved the concept.[38]

At first the bureau envisioned only a limited role for NOTS. When McLean sat in on a meeting of the coordinating committee, he argued persuasively against the inflexibly nuclear nature of the RAT replacement as initially envisioned. Fearing that the proposed weapon would represent saber rattling to the world powers, McLean offered to develop a rocket-propelled weapon capable of operation as either a nuclear depth charge or a lightweight acoustic-homing torpedo. BuOrd agreed that this flexibility would be advantageous, but assigned development of the non-nuclear version to NOL.[39]

McLean called on Barney Smith, by then head of the Rocket Development Department's Surface Weapons Division, to talk with NOL about what NOTS' role would be in what was by then known as the Antisubmarine Rocket (ASROC). Donald W. "Don" Moore recalled receiving a phone call one Friday afternoon from Smith, who had been in Washington listening to a daylong review of NOL plans for ASROC. The NOL group believed that thrust termination of a solid-propellant rocket was not a practical way to control water entry and instead proposed that the rocket use liquid propellant. That alternative didn't make sense to Smith. "We need to show them how to do a thrust termination on a rocket motor," he told Moore.

That was the sort of technical challenge Moore and his compatriots relished. He called on Saholt and Chuck Bernard, and the three began work immediately. As Moore recalled the trio's activities:

> . . . Chuck and Jerry designed a primacord arrangement to put on the forward dome of the rocket motor, so that it would cut out three holes in it, and . . . there'd be a negative thrust, and they would terminate the thrust of the rocket motor, and separate it from the rest of the weapon. I built a little timer to initiate that, fire flash bulbs so that the cameras could tell the live warhead worked. So we designed that on Friday night and Saturday and built it in the shop on Saturday and Sunday and fired it on Monday morning. We developed the film Monday afternoon before Barney got on the airplane and took the red-eye back and showed everybody that 'You guys ought to give us a shot. We know how to do things,' and we got ASROC.[40]

The station got ASROC, all right, but to the dismay of Barney Smith and his team, BuOrd assigned the lead to the Pasadena Annex.[41] Smith complained to Wertheimer, who counseled him, "A man has time either to do the work or get the credit for it. He can't live long enough to do both. You'll get a lot more done if you don't mind who gets the credit." Furthermore, Wertheimer said, "ASROC will be in the arsenal for a long time. Just take private pride in it." Recalling Wertheimer's remarks years later, Smith conceded, "He was right." But at the time, Smith and his team complained bitterly about a decision that they saw as favoring Pasadena politics over China Lake technical competence.[42] In February BuOrd assigned NOTS overall technical responsibility for ASROC (then going by the unwieldy designation of ASROC/RAT) with the Pasadena Annex taking the lead.[43]

While planning for ASROC went forward, Phase B RAT continued. Despite several problems encountered during its final months of development, a prototype system incorporating several payload modifications showed promise on board *DeHaven* (DD-727) during 1955–1956. In November 1956 the Navy unveiled the RAT program to 60 newsmen in Pasadena and announced that the new rocket-thrown torpedo would enter the fleet in 1958. Despite problems and delays, the weapon was on schedule.[44]

DeHaven firing RAT on the NOTS Sea Range, 29 January 1957, during BuOrd evaluation.

After a successful BuOrd evaluation in January–April 1957, an OPDEVFOR evaluation began off Key West, with Librascope managing a program involving 150 rounds fired against submarines. In August Commander J. J. O'Brien, officer-in-charge of the Pasadena Annex, reported to the Research Board when the evaluation was half finished, "The hit score to date is 45 percent, with no trouble reported, and no requests for help." By late November the news in the Research Board was that "RAT is hitting well, and is apparently going into 13 ships next fiscal year."[45]

On 10 February 1958, the Navy began presentations on RAT to the nation's news media in Pasadena and in Washington. Ironically, the program was already in its last months of existence, with RAT's performance acknowledged to be ineffective against rapidly moving targets. Ten months later the program was cancelled, primarily because of "the inadequate payload in the Mk 43-3 torpedo."[46]

RETORC and Its Descendents

During the heyday of the RAT program, UOD also looked ahead to newer ASW torpedoes, urged on by Navy submarine experts, who were uncomfortably aware that America's submarines could not carry out their mission against nuclear submarines with the existing torpedoes. A quantum leap to a new generation of torpedoes would be needed, and with that in mind, UOD proposed the Research Torpedo Configuration (RETORC) program in May 1954.

By selling the program to BuOrd, UOD leaders were able to get sufficient funding for several groups of Pasadena engineers to work on knotty torpedo problems in hydrodynamics, pumpjets, power plants, structures, and guidance and control. To Jim Campbell went the task of determining how reflections from the target were affected by the properties of the ocean. To Shelby Sullivan went the assignment to devise coherent detection techniques. UOD engineers then applied these new insights to hot-gas engines, acoustic systems, and liquid fuels.

U.S. Navy photo LHL-P 5794

Test at sea of the EX-8 torpedo, later designated Mk 46.

Torpedo Mk 46 Mod 0 ready for shipboard launch, July 1959.

Although RETORC was primarily a vehicle for improving basic knowledge, a prototype torpedo known as EX-8 was an important outcome. Powered by a hot-gas engine and propelled by a pumpjet, this revolutionary research vehicle had a top speed of 45 knots, a propulsion range of 12,000 yards, and an acoustic range of 1,500 yards. With EX-8 feasibility demonstrated, the torpedo was redesignated Torpedo Mk 46 Mod 0, then assigned to Aerojet-General for fabrication of evaluation hardware under the technical direction of UOD. A lightweight antisubmarine torpedo using both active and passive acoustic search and homing, Mk 46 could be launched by rocket, fixed-wing aircraft, helicopter, blimp, or surface vessel. The station requested the responsibility for design cognizance as well, but BuOrd kept that role for itself.[47]

Design funding began in 1958, but the early development process became a textbook case of what can happen when the people who created a product are taken out of the picture at the wrong time. When Aerojet-General began making changes to both the design and the testing procedures, the company introduced new problems that caused the program to fall behind schedule and run over budget. The torpedo ultimately became a success, but only after the bureau returned it to Pasadena Annex for redesign and troubleshooting, then reassigned it to Minneapolis-Honeywell Regulator Company. Hack Wilson later attributed the difficulty to Aerojet's faulty assumption that civil servants "don't know how to design a thing for production anyway."[48]

Another outgrowth of the RETORC program was the Mk 48 torpedo, conceived of as a heavyweight torpedo having a non-nuclear warhead and the capability of attacking high-performance nuclear submarines in a countermeasure environment. Development of the Mk 48, which occurred in the 1960s, again involved the necessity for the Navy to call on in-house expertise to ensure excellent contractor performance.[49] Versions of both Mk 46 and Mk 48 continue in the Navy's torpedo inventory today.

Annex Accomplishments

Work at the Pasadena Annex during the mid-1950s built on the theoretical foundation established during the previous decade to encompass broader responsibility for complete torpedoes. This responsibility spread rapidly in the years after the Korean conflict until UOD became one of the nation's primary developers of antisubmarine weapon systems. In support of this work, annex leaders emphasized a three-fold approach: applied research, development of components and systems, and technical direction of contractors.[50]

The Pasadena Annex built on the solid skills of its people to emerge as a national leader in development of small, lightweight torpedoes and research in acoustics of the ocean as they affect underwater weapons and their targets.

14

Golden Years

In 1954, in response to a communication breakdown between the station's two top leaders, members of the NOTS Advisory Board convinced the BuOrd chief to appoint new leaders more likely to adhere to the unwritten yet tangible rules and traditions influencing the division of tasks in China Lake's "head shed." After the selection of Dr. William B. McLean as technical director, a smooth, accomplished civilian leadership team emerged, with Haskell G. Wilson helping expedite the technical accomplishments and LaV McLean contributing boundless energy to the life of the community. With the arrival of a new commander, Captain Frederick L. Ashworth, the station entered a golden era with a cohesive military-civilian leadership team meeting a series of demands from within and without.

Brown's Departure

Fred Brown's tenure as technical director lasted less than three years, with his departure from China Lake's top civilian job hastened by his volatile relationship with Captain David Young, NOTS' skipper. When Thompson discovered the lack of harmony between the two top leaders, he urged Brown to make efforts to reconcile with Young, "a very able fellow" whose abilities had impressed Thompson ever since Young visited Dahlgren for PG training early in his career. In 1953, however, after several trips to China Lake to talk with both men, Thompson began to believe that the problem was not Brown's alone, that Young may have had an agenda from higher up, perhaps from the Secretary of the Navy himself, to reassert military dominance at China Lake.[1]

As problems between Brown and Young intensified, reverberations sounded throughout the village.[2] The NOTS Advisory Board stepped in to perform what Hack Wilson later termed "a very yeoman service" to resolve the situation. The board's direct involvement apparently began when Parsons, by then deputy chief of BuOrd, came to China Lake to sit in on the board's November 1953 meeting. The minutes contain no reference to the Brown-Young situation, but participants recalled that an important reason for Parsons' visit was to discuss the subject, by then the station's most burning issue.[3]

Sadly, this visit was Parsons' last. His widow recalled that before his 5 December 1953 death he spent "an awful lot of time" his last months thinking about the trouble between Brown and Young, and "finally got it straightened out somehow or other." Much of that straightening out appears to have occurred during a November visit to China Lake, when Parsons apparently reached an agreement with Advisory Board members that if they would find another job for Brown, he would convince the chief of the bureau to assign a new commander to NOTS.[4]

In January Bureau Chief Schoeffel traveled to the desert, ostensibly to discuss a proposed revision to the NOTS Organization Manual. Young had directed this revision, which reaffirmed the preeminence of the commander, with the technical director and executive officer acting for the commander in their designated areas of assigned responsibility. Brown and Young had reached an impasse, however, on the reporting chain for the executive officer. The organization Brown favored would have the station's Number 2 military officer reporting to the commander via the technical director. The organization Young wanted would put the technical director and the executive officer on the same organizational level, each responsible to the commander for a clearly delineated set of responsibilities.

As the Research Board discussed this matter with Schoeffel, Captain Robert H. Solier, the executive officer and designated owner of the turf under dispute, prudently maintained a low profile. Other board members observed that Young's proposed statement "introduced no changes in the way the station had been operating, and that the statement was probably more realistic than previous ones."[5] Schoeffel then selected the alternative Young preferred. As Schoeffel described his decision:

> At that time I rendered the decision in favor of the second form and enjoined upon Captain Young and Captain Solier the dictum that the service organizations directed by the Executive Officer must be imbued with the spirit that the Station exists for the purpose of conducting the technical program, the responsibility for which is delegated to the Technical Director.[6]

In the meantime, members of the Advisory Board were quietly using their superb network of professional contacts to locate another suitable job for Brown. Wallace Brode discovered that the Bureau of Standards needed a director for its Boulder, Colorado, laboratories, a position that seemed ideal for Brown. With the concern for Brown's future thus assuaged, board members were ready to take the next step to stabilize the station's civilian leadership. Upon the board's return to China Lake in March 1954, members were ready to put their recommendations on the record. "Smooth operation can only be attained by having in the top civilian and military positions persons who understand and believe in the joint civilian-military administration," said the minutes, adding that the board "reviewed at length the present administrative difficulties at NOTS after consultation with the commander, the technical director and a number of others."[7]

Stroop had been following China Lake's situation with interest from his Washington position on the Weapons Systems Evaluation Group, and although he was not present at the meeting, he received confidences from several who were there. He later commented:

> . . . I think that report from the Advisory Board was what got rid of Fred Brown. . . . as the Advisory Board was getting ready to leave, they went into Fred Brown's office and handed him a copy of the report in the rough and said, 'This is what our report will look like.' And that's the way he got the sentence. He read the report and found the last sentence that the Technical Director be replaced. . . . He must have realized that his usefulness as Technical Director was over with the Advisory Board making that statement.[8]

Brown resigned almost immediately and accepted the job Brode had found for him. At Brown's going-away party in the Michelson Lab cafeteria, emcee Commander Stanley W. "Swede" Vejtasa, Naval Air Facility commanding officer, moved graciously through the traditional presentations. Nevertheless, the atmosphere was strained.[9]

"I don't think that Fred Brown was wrong; he was just there at the wrong time," McLean later observed as he looked back on his own successful tenure as technical director. He added:

> One of the reasons I went to China Lake is that I liked the program that Dr. Thompson was trying to set up. And I really wanted to keep the lab following in those lines, which was to move the technical work out of the Bureau of Ordnance and do it at the laboratory. Now Fred Brown was equally dedicated to that objective, but he was dedicated to moving it out of the Navy, in addition to moving it out of Washington, and that wasn't very acceptable at that time.[10]

New Civilian Leadership Team

Even before the Advisory Board's November 1953 meeting with Parsons, members had fastened on the idea of selecting Bill McLean as China Lake's next technical director. Indeed, Stroop and Lauritsen had discussed that possibility with McLean while Stroop was still at NOTS. Levering Smith remembered that the Advisory Board "played a major role in supporting and almost in choosing Bill McLean to succeed," so that the usual nationwide search did not occur. This irregularity was acceptable in Washington, where McLean was highly respected. In addition, as Smith pointed out, the prestige of the Advisory Board members made BuOrd officials "much more willing to accept recommendations from the Advisory Board regarding the technical director than if it had been a board of less stature."[11]

On 19 March 1954, McLean accepted Bureau Chief Schoeffel's official offer of the position. A delighted Schoeffel was preparing to announce the event when he realized that the continued existence of a Public Law position had to be officially approved by the Secretary of the Navy before it could be filled. "I had carried out all the negotiations in regard to this matter personally rather than through the normal channels of the bureau, a situation for which I most heartily apologize to all concerned," Schoeffel wrote McLean, adding,

> I immediately called Mr. [James H.] Smith, the Assistant Secretary of the Navy for Air. . . . He has directed me to ask you for your views regarding the organization of the Station, both in the broad sense of its organization as one in which we endeavor to obtain an integration of civil and military background and experience and also in the somewhat narrower sense of the position of the Technical Director within the organization of the Station.[12]

Answering that he was "very happy to be asked about my opinions," McLean identified his primary responsibility as insuring that

> [T]he work of the Station is so organized that it will yield the best return for the country and the Navy from a long range standpoint. . . . I believe an organization will function most effectively if all lines for achieving action are kept as short as possible. An organizational structure should never be set up merely to achieve communication. Effective action in development work can result only if communication proceeds regardless of organizational channels.

To further illuminate his views on the military-civilian relationship, McLean sent Schoeffel a document, "Comparison of Attitudes of Scientists and Naval Officers which may result from differences in Character and Training." In McLean's opinion, the scientist respects only opinions based on fact and determined by experiment and follows the belief that "it is more necessary to be correct than to be legal," whereas the military officer defers to the opinions and obeys the orders of a higher-ranked officer in the belief that "it is more necessary to be legal than to be correct." The scientist develops a questioning attitude "since nature recognizes no human authority" and delays decisions to be certain of the facts, whereas the military officer acts on regulations and makes immediate decisions "since any decision is better than none in an emergency."[13]

McLean found these comparisons important enough that he sent a copy to Representative R. Walter Riehlman's Military Operations Subcommittee that

June in response to the committee's invitation for him to testify. The Riehlman hearings, which focused on military-civilian relationships as they affected the administration of the DoD R&D program, found that neither extreme military control nor extreme civilian control offered the best R&D management model.

U.S. Navy photo

Bill McLean at his desk.

McLean and his department heads were pleased when the Riehlman Committee singled out the military-civilian management teamwork of the BuOrd laboratories as the model for other laboratories to follow.[14]

When McLean became technical director, he had been a NOTS employee for nearly nine years. His hands-on approach to the station's work and the highly social lifestyle his wife organized for him after hours put him on a first-name basis with hundreds of China Lakers.[15] As might be expected, his promotion to the station's top job was occasion for a big, boisterous celebration.

A few department heads privately harbored doubts about how some aspects of the job would be accomplished. "I suppose some . . . were worried because he was not known as an organizer," Newt Ward said later. "What he was interested in was clever weapons. He was a technical leader, not an administrator."[16]

McLean also recognized these traits in himself. As he rose from branch to division to department leader, he made sure to have a second-in-command who assumed much of the administrative burden. Don Moore, who was a constant in the shifting group of creative individuals surrounding McLean, recalled a conversation about the two-person management team. "Bill had said it really wouldn't make any difference which one was technical director," Moore recalled. "But he felt that all organizations of the NOTS type should have that type of combination, where one person was the administrator and the other was the innovator."[17]

As head of AOD, McLean had relied on Ward to handle administrative matters. With McLean's rise to technical director, Ward had taken over leadership of AOD, thus ruling out his further performance in the complementary administrative role. McLean had been counting on Levering Smith's expertise in the post of associate technical director, but by the time McLean became technical director, Smith was no longer on-station. The quietly effective naval officer had been at NOTS for an extraordinarily long tour—nearly seven years. The rumor around China Lake was that his sudden reassignment in early May 1954 to Las Cruces, New Mexico, as commanding officer of the Naval Ordnance Missile Test Facility at White Sands Proving Ground was punishment for being overly sympathetic to civilians.[18] Smith himself dismissed that notion. "I didn't ask to leave," he said, "but from the general personnel planning point of view, I just had the right background" for the White Sands job.[19]

With Smith's departure, Thompson had appointed Dr. F. E. Lowance, who had been at China Lake for only three months, to the associate technical director position. Within nine months of McLean's ascendancy, Lowance left the station to become director of research for the Westinghouse Air Brake Company in Pittsburgh. Emory Ellis became what Ward called the "potentially


U.S. Navy photo, China Lake archives

Hack Wilson receiving the L.T.E. Thompson Award from Thompson himself, 15 November 1957.
(See Appendix B for Thompson Award winners through 1961.)

The McLean-Wilson leadership team in action.

Immediately behind Wilson is Dr. Glover S. "Dud" Colladay.

logical candidate" to replace Lowance, with Ted Toporeck and John Shenk also aspiring to the position. But McLean preferred to look for someone who matched his own work style. He talked to each of the department heads, and the name Haskell G. Wilson soon surfaced. After Wilson's arrival during the height of the Korean conflict, he had become associate head of the Test Department in 1951 and head of Central Staff in January 1954. He had never worked directly with McLean before, but had quietly accumulated goodwill throughout the station for his steady nature and wise decisions.[20]

According to Wilson himself, the kind of person McLean needed was "not someone to compete with him technically, but someone who had an interest in the management and the organization." With both men clear about their roles, they soon worked out a harmonious partnership. For the first several months, they got together at least once a week to develop their working relationship. Wilson recalled that decisions were as simple as "O.K., you're delegated to look after that and my philosophy or policy on that is the following. And when you run into something we haven't talked about, come back." Eventually Wilson developed a list of things he was responsible for, with perhaps the most challenging the responsibility for fostering good working relationships. Years later, both McLean and Wilson commented that they nearly always agreed about who would handle which problem. Disagreements were invariably resolved by simply talking things over. The interplay between the two personalities produced extraordinarily strong leadership. The McLean-Wilson team would lead the station's technical effort for more than a dozen years. As Pierre Saint-Amand summed up the partnership, "Hack saw to it that things got done, and Bill saw to it that there were lots of things to do."[21]

Several other significant organizational changes occurred at NOTS during the early years of McLean's leadership, starting with a reorganization of the weapons-planning organization. At Thompson's insistence a small central evaluation and planning group had been set up at NOTS in 1950. Brown, too, had taken a special interest in planning and analysis and had required all department-level evaluation groups considering new programs to first discuss their plans with the head of the Central Evaluation Group.[22] When McLean became technical director, he reassigned Ellis from leadership of the Rocket Department to become the head of a new Systems Programming Group, "concerned with the broad aspects of weapon systems, with a view to the formulation of policy and programs relative to current and projected technical objectives of NOTS."[23] Ellis had flourished under Thompson's low-key leadership approach, but he found McLean's less orderly, more intense style of work difficult. After a short search for other employment, he left the station that December for Rheem Ordnance Laboratory in Downey.[24]

By the following month, the new Weapons Planning Group was in place. Bothwell, the new head of Code 12, had just returned from a grand tour of planning organizations in other parts of the Department of Defense. Finding little evidence of long-range planning, he recommended "that if there is to be long range planning in the weapons systems it will have to be done in the development establishments since there is no central activity performing this function." The new Code 12 combined the weapon-evaluation functions of the Central Evaluation Group with the engineering feasibility studies of the Systems Programming Group.[25] With establishment of this central planning group, NOTS set a precedent that the Naval Air Development Center and the Navy Electronics Laboratory soon followed. "This onset of organized operations analysis activity within the Navy laboratories represented a fundamental recognition that detailed study of military operations and requirements had to be a continuing part of the R&D cycle," said Carl L. Schaniel, who would become the head of the group in 1965.[26]

One important type of task closely allied to operational analysis was the direct support provided by technical experts visiting the fleet. Although the value of troubleshooting technical problems on the operational scene had proved its worth during the Korean conflict, only a small number of people were officially assigned to that function. In December 1952 the station had set up fleet service as an organized, continuous activity within the Central Evaluation Group. The major functions assigned to the group were to gather operational and tactical weapon information, to help operating military personnel with new ordnance introduced into fleet use, and to report back on problems encountered during those endeavors.[27] In September 1953 the Research Board agreed that the unit's size should stay at just three civilians, two assigned to China Lake and one to Pasadena. At the suggestion of the experimental officer, Captain Tom Connolly, the plan was for a naval officer to come along for each of the major trips.[28]

That suggestion pointed up the importance to fleet support of the experimental officer and his military team, and in August 1954, when Francis C. "Frank" Wentink began spending his entire time introducing first the 2.75-inch FFAR, then Sidewinder, to the fleet, he was organizationally assigned to the Experimental Office. By 1957, the work would grow to the point that an enlarged In-Service Support Division would be established in the Engineering Department under the leadership of Ted Lotee.

Another sort of reorganization, one McLean couldn't avoid, occurred in late 1955 when Pat Patton, Gerry Makepeace, Tony Ozanich, and Hubert Bennett left NOTS to form their own private-enterprise precision foundry, Sandshell Corporation. Although the station had lost many competent people before, the prospect of simultaneously losing two department heads—Patton of the Rocket Development Department (Code 40) and Makepeace of the Propellants and Explosives Department (Code 45)—sent ripples through the organization. McLean minimized the upset by quickly moving two ambitious division heads into the department-level jobs: Howie Wilcox from AOD's Development Division (Missiles) into the Code 40 position and Quentin

Courtesy Harold H. Patton

Pat Patton admiring a model rocket, an October 1955 going-away gift.
From left are Earl Loomis, unidentified, Patton, Frank Foster, and James C. McDonald.

Elliott up within the Code 45 organization, where he had been head of the Propellants Division.

The Sandshell team's departure also became a good opportunity for a farewell bash. The "four male suspects," were accused of the "crime of jumping ship" and were presented with the locally infamous Dust Devil certificates, comic citations written in a baroque style and customarily never read. In a less tradition-encrusted ceremony, McLean gave each of the wives involved a large bag of groceries, explaining that at least they wouldn't starve if the business didn't survive. The partners took more than good wishes, plaques, and groceries with them; the China Lake community, aware of the technical expertise, invested heavily in the Sandshell enterprise.[29]

Wilcox almost immediately renamed his department Weapons Development. The new department had a broad mission: development of guided missiles, surface weapons, air-to-surface weapons, and air-to-air weapons, with a continued interest in weapons components and liquid propellants. For public consumption, the department was described as "streamlined and bolstered with new skills to meet the challenge of the guided missile age."[30]

C'est LaV

In the close-knit community of China Lake, the wives of the military and civilian leaders were expected to take leadership roles, too. For the wives of the top leaders, in particular, these duties encompassed coordinating the social life of the community to mesh with and support the station's technical and administrative responsibilities. The commander's and technical director's wives were expected to entertain visiting dignitaries, serve as leaders of community-service groups, welcome newcomers, organize suitable festivities to celebrate holidays and special events, and ensure that the schools and other social services had the community support they needed. Some wives were more skilled at these responsibilities than were others. None was more adept than LaV McLean. As the wife of the technical director, she set the tone for the China Lake community, which in turn accepted and supported her.

She had been a vital force in the community from the day she arrived in 1945. Her trademark optimism had swept her past the discovery that when her husband had promised he would take care of getting the family household essentials moved to China Lake, he had been thinking not of the china or silverware but of his treasured collection of Sears, Roebuck and Company catalogs in which he could browse for tools. She would have preferred the wedding gifts to the catalogs, of course, but "LaV rolled with everything," said

LaV McLean and some of her students at Burroughs Junior High School (now Murray Middle School).

Polly Nicol, a close family friend from those early days onward. "She didn't let material things bother her."[31]

A job teaching physical education at Burroughs Junior High School gave LaV visibility among all levels of China Lake society. Many of her students didn't know until years later that the friendly, chatty lady who insisted that they all learn to dance was also the wife of the station's top civilian. She also made a point of visiting her friends, acquaintances, even strangers in the hospital after school, always taking along loaves of her homemade nut bread.[32] Polly Nicol recalled:

> [O]ne time, she found this family sitting on the grass, and they were looking so dejected. . . . they had had an accident on Highway 6 or 14. . . . One little boy was seriously injured and was hospitalized there in the Ridgecrest Hospital for an indefinite time, probably at least a week. . . . I think there were two other children. The parents didn't have any extra funds. They were just getting by and on their way home from a vacation, so LaV took them home. They stayed at her house for the whole week . . . those people still stay in touch with her.[33]

As previous chapters have shown, Bill McLean led a seamless life; the concepts "work" and "play" were synonymous for a man whose vocation was also his avocation. His interest in matters technical resulted in situations that must at times have tried even his exceedingly tolerant wife. LaV recalled one incident:

> [W]e ordered a Sears and Roebuck washing machine and we were down in Los Angeles and picked it up and we got home and I was really looking forward to getting the laundry done. It was a combination washer and dryer. I was thinking that it would be good because I could put the laundry in and when I got home from school, it would all be done. I went out there and there it was all apart with the pieces laying on the floor and I said to Bill, 'What are you doing?' and he said, 'I just wanted to see how it works.'

Fortunately, McLean had the mechanical aptitude necessary to put back together what he had taken apart, and the machine worked splendidly for many years thereafter.[34]

A China Laker describing LaV's personality to a newcomer would invariably bring up as an illustration of her practicality and good humor the story of her getting trapped in a Dempsey Dumpster, one of the large transportable bins in which residents deposited their trash. As the lady herself remembered the incident, she discovered she had lost a good sterling fork after a formal dinner party. "So I got in the dumpster to hunt for it, and the door closed tight, and there I was, in the dumpster! So that's a fact!" she said. "But I found the fork."[35]

Bill McLean willingly relinquished decisions about social matters to his spouse. So comfortable was LaV as social arbiter that friends jokingly called her General Bullmoose even as they depended on her decisiveness. At the family's summer cabin on Lake Chelan in Washington state was a 21-foot fiberglass boat, which McLean purchased and christened "C'est LaV." On one family trip to Lake Chelan with the Nicols, McLean privately talked with his wife and suggested that she try not running the show. She complied, and the rest of the party discovered after several days of chaos that they needed LaV to get them back into line.[36]

The McLeans were never impressed with their own position of eminence at China Lake, and when Bill McLean became technical director, they stayed put in the same house on Lexington Avenue they had lived in since he became a division head rather than moving into the larger, more prestigious housing for which his new position made them eligible. Their friends came from all levels of the military-civilian workforce.

The McLeans also welcomed visiting VIPs with memorable hospitality. "We always made plenty of food because you never knew who might come, and I always told people don't call me ahead," said LaV. "One reason was that I felt that I would have to clean up the house ahead of time." On one occasion, several China Lake couples were invited to a dinner party with a visiting admiral and his wife. Elizabeth "Billie" Hise recalled:

A snack break at the McLean home.

From left are Walt LaBerge, Newt Ward, Don McLean, Bill McLean, LaV McLean, Howie Wilcox, and Mark McLean.

> There were white linen tablecloths and silver and crystal on the table and then you [LaV] got a call. I think there were two Navy families who had been on base and you knew them well. They were just passing through the area and had called to say hello. One family had two or three children. You invited them to come and join us, in fact you insisted . . . we had to bring in the picnic table and put it at one end of the table since there wasn't enough room otherwise. Also there wasn't enough china for all so we used some paper plates and stainless steel tableware.[37]

Much of McLean's influence in the Navy could be directly credited to his wife, according to many who saw her in action. Not only did she win over important Washington visitors with her charming personality and great parties, but she also made certain her more reserved spouse joined in. Bill McLean was notoriously bad about remembering names, so at every party LaV, who had a prodigious memory for personal detail, would be there whispering vital information in his ear. According to P. D. Stroop, "LaV was Bill's public-relations man."[38]

"She had a remarkable grace," said LaBerge.[39]

Young's Departure

One person who made no secret of his relief that Brown was gone was the commander himself. But the ambitious Young must have shortly realized that despite his own sterling background, the quarrel with his civilian counterpart had tarnished his prospects for an illustrious Navy career. Young had also taken several actions that appeared high-handed to the station's civilian iconoclasts. Perhaps the least significant of these may serve as a symbol of his difficulties with China Lakers. He had decided to have a helicopter pilot deliver him home for lunch. During the attempted landing on the lawn adjacent to his residence, a rotor blade clipped a tree and the landing became more like a crash. He was unhurt, the debris was swept up, and nothing about the incident appeared in print. As might be expected, though, all of China Lake knew about the crash landing almost immediately. Criticism was not so much because he had ordered the stunt but because he tried to hush it up afterwards.[40]

Young also displayed increasing irascibility toward his top deputies—probably a sign of impending health problems, as well as of the stress he was under.[41] When Brown left and the adrenaline-producing conditions of the previous six months suddenly eased, Young's health just as suddenly deteriorated. In early August he reported to the naval hospital in Bethesda, Maryland, for "observation of a heart condition." Captain Robert F. "Mike" Sellars, the station's popular executive officer, took over temporary command. The *Rocketeer* reported over the ensuing few weeks that Young was improving. Released from the hospital in November, he returned to NOTS and assumed command again, although evidently not with his former intensity.[42]

In January 1955 the Secretary of the Navy asked a high-ranking panel to "consider the current operations and programs of the Naval Ordnance Test Station, Inyokern, in relation to the operations and programs of other activities of the Navy and of the other Armed Services which are engaged in similar work, and such other matters as are considered pertinent."[43] Those other matters involved individual and joint interviews with McLean and Young to discover how they were getting along. Suitable help with this sensitive aspect of the task was assured when Stroop (by then a rear admiral and deputy chief of BuOrd) became a panel member.

The panel convened for a February meeting in Washington with McLean, Young, and Wilson. In the initial session, at which all three NOTS visitors were present, panel members listened to Young's assurances that all was serene at China Lake and that he and McLean were functioning well together. When the panel met privately with McLean, he confined his remarks to various aspects of the station's technical work. The panel appeared satisfied with these assurances, as well as with other aspects of the work at NOTS, and issued a report in May 1955 finding that "the Station is being operated satisfactorily and effectively."[44]

The NOTS Advisory Board, meeting that May, commended Young for his "fine work at NOTS and the outstanding results he has achieved under very difficult circumstances" and gave McLean a commendation with similar wording.[45] Much more was going on at that meeting than the minutes reflect, however. Among the guests was Rear Admiral Frederic S. Withington, who had succeeded Schoeffel as chief of BuOrd the previous December. Withington, an Academy man, had earned admiration within the naval establishment for his openness and decisiveness. He solicited a frank assessment of what had gone wrong between Young and Brown. Hack Wilson, who was present at the meeting, recalled that when Withington "heard all the gory details, he really concluded that if two men could get so out of control as these two had, that neither one had done his job."[46]

Withington took action, and a mere month later Young received retirement orders. A low-key ceremony in the commander's office and a restrained party at the Officers Club marked his departure from NOTS on 30 June. He put a brave face on the turn of events, but he was bitterly disappointed at this truncation of his brilliant naval career. "Poor fellow," said Gil Plain, who was present when Young read his orders, "he had tears in his eyes as he read them."[47]

U.S. Navy photo 7555-6

Captain David B. Young and his wife Jane at his retirement party.
Commander Thomas J. Walker looks on at right.

Even with the rapidity of Young's departure, Stroop had already decided whom he wanted for the top job at NOTS. The next commander would be Captain (later Vice Admiral) Frederick L. "Dick" Ashworth, an aviator with a background as illustrious as Young's. When Ashworth learned that he would be reporting to NOTS, he was at sea with orders in his pocket. As he recalled:

> . . . I got a letter from Admiral Stroop that said I was going to China Lake. So I wrote him back, and I said, 'Well, that's all very fine, but I have orders to the Naval War College.' I got a nice letter back from him. 'Well, that's all very fine, too, but you are going to China Lake in command.'[48]

Ashworth's reporting date was set for 12 August. In the meantime, the station's top job briefly became the official responsibility of Sellars, the only submariner ever to command the Navy's "desert ship." He was officially NOTS commander for just six weeks, but his leadership actually encompassed several previous months. As the executive officer he had been acting as commander during Young's illness.

A Minnesotan and a 1934 graduate of the Naval Academy, Sellars had seen World War II combat duty as commanding officer of three different submarines. He became familiar with NOTS when he served in 1950–1952 as BuOrd technical liaison officer at the Pasadena Annex. He left briefly to command Escort Squadron 16, then returned in 1953 as officer-in-charge of the Pasadena Annex, becoming the station's executive officer in June 1954. One testament to his effectiveness in that position was an effusive award he received at a 1955 dinner of the Kern County Board of Trade. Sellars earned praise for "aggressive leadership in . . . helping to create a relationship between the military and civilians that stands out as a national hallmark."[49]

U.S. Navy photo

Captain Robert F. Sellars.

When Sellars took command of NOTS, he had already received orders to take command of the Navy's first guided missile ship, *Norton Sound* (AVM-1). He loved the people and the work at China Lake, though, and he attacked his temporary responsibilities with gusto.

Sellars had a keen sensitivity to the difference between NOTS and the usual command, a difference he joked about during a visit to the desert a few years later. As Pat Patton recalled the conversation:

> I said, 'Mike, now that you've been away for a while, what do you think of China Lake?' He said, 'Well, let me tell you how it is in the Navy.' He said, 'I'm up on the bridge, and here's these ships streaming off behind me in all directions, and I look around, and I say, 'Turn left.' And the whole damn thing turns left. And all they ever ask me is, 'How far?" He says, 'That's what I think of China Lake. Because at China Lake if you said 'Turn left,' they'd say, 'Why?'[50]

Firm Hand at the Helm

Stroop retained close ties with his former desert command, exercising his considerable authority whenever he could to ensure the station's continued health and prosperity. His selection of Dick Ashworth to command NOTS brought to China Lake a man whose experience and training qualified him superbly for the job. Ashworth was a 1933 Naval Academy graduate. After his first sea duty on board the battleship *West Virginia* (BB-48), he was designated a naval aviator in 1936 and later completed the postgraduate course in Ordnance Engineering (Aviation) at Annapolis. When World War II broke out, he was serving in BuOrd's Production Division. Reassigned to combat duty, he received the Distinguished Flying Cross for his heroism as commanding officer of a torpedo bomber squadron in the Solomon Islands area. He became staff air officer for Amphibious Forces Central Pacific during the Gilberts and Marshall Islands campaigns and received the Bronze Star Medal for "outstanding service . . . in solving the numerous tactical and strategic problems encountered during a bitterly fought campaign."[51]

Following 1944 service at the Naval Proving Ground, Dahlgren, Virginia, Ashworth entered the history books with his next assignment. He was called to Los Alamos in connection with the development and testing of the atom bomb. The nation's leaders considered the highly secret Project Y—the Manhattan Engineer District—to be of supreme importance to winning the war, and Army Lieutenant General Leslie R. Groves had his pick of scientists and military officers to support the project. Ashworth's modest explanation for his own selection was that "Groves had a great propensity to have spares of everything, and I think that I was the spare for Admiral Parsons."[52] Groves decided that each bomb crew would need a weaponeer, someone who would ensure that all technical aspects of the weapon were correct before its release, then give the order to drop the bomb at the proper moment. He selected Parsons as weaponeer for the bomb dropped on Hiroshima on 6 August 1945. Ashworth performed the same role three days later for the Nagasaki bomb. For this accomplishment he was awarded the Navy's Legion of Merit and the Army's Silver Star Medal. Groves, not an easy man to please, later praised Ashworth's "determination and great courage" and noted that "he turned out to be a ten-strike in every way."[53]

After the war ended, Ashworth reported to OPNAV for duty in charge of the Air Applications Section, Office of the Director of Atomic Defense (Op-36). This assignment gave him the opportunity to serve again with Parsons, who headed Op-36. There Ashworth earned a Gold Star in lieu of the Second Legion of Merit for his outstanding service as the officer in charge of preparing the atom bomb used in Test Alpha of Operation Crossroads, the nation's first large-scale weapons effects test.

U.S. Navy photo

Captain Frederick L. Ashworth.

His participation in these events made him a natural choice, when the Atomic Energy Commission was created in 1947, to become the first executive secretary of the powerful Military Liaison Committee to the AEC. In October 1948 he became executive officer of Composite Squadron Five (VC-5), the Navy's first Atom Bomb Squadron. When Parsons offered Ashworth command of the squadron, he deferred to Captain John T. "Chick" Hayward, another famous name in China Lake's history. Ashworth then told Parsons, "But I'd like to have command of the second one." He got that command when VC-5 split into two squadrons the following January.[54] Students of military history consider both men important figures in the Navy's transition from the pre-World War II dominance of the battleship to a new emphasis on carriers as launching platforms to project military force against adversaries located anywhere within the range of carrier aircraft. The creation of VC-5 and VC-6 was a signal victory in Hayward's and Ashworth's campaign to win a place for special weapons in the new Navy.[55] From late 1949 to late 1950 Ashworth served as executive officer of the carrier *Midway* (CVB-41). He had another tour with the AEC and a year's sea duty in command of the seaplane tender *Corson* (AVP-37), before he arrived in China Lake on 12 August 1955.

Workers at NOTS soon viewed Ashworth as one of the station's most effective commanders. Describing the principles of operation as "the very life blood of the laboratory," he realized that too much control on the military side or too much intellectual arrogance on the civilian side could destroy the principles' fragile balance. Ashworth saw that he could contribute to keeping that balance. "It's so terribly important that the scientific ingenuity and creativity and civilian technical direction be given its complete head," he commented later. "The minute the military get in there and try to control it, you're headed for trouble." He later recounted a conversation that illustrated his commitment to that philosophy:

> I recall one time at the swimming pool during my tour here as commander a newly arrived officer sat down next to me. His first remark was, 'It's ridiculous the way civilians have taken over this place.' Well, I backed him into the corner and set him right. I explained that this is a civilian operation supported by the military and that he had better cooperate.[56]

Straight-talking and decisive, Ashworth was the kind of military leader China Lake's maverick civilians found most compatible. He combined his belief in the station's operating principles with a firm view that his own leadership should be focused toward Washington as an advocate of the technical priorities set by McLean and his scientists and engineers. Ashworth's experience at NOTS convinced him that the breakthroughs resulting in "our most effective long strides in weaponry" were most likely to come from rebels and nonconformists, people he later described as "the kind of present day goose that seems to be laying the golden eggs we need for military surprises." So strong was the creative urge toward rebellion, he said, that "some of our better laboratory people" did their best work when they were forbidden to do it. "It would be unthinkable to try to manage these people from Washington," he concluded.

Equally important, Ashworth believed, was the other component of the team, the military officers who represented the station's ultimate customer in the fleet. He later summarized the advantages these officers brought to the laboratory community:

> The well-trained officer, thoroughly familiar with fleet operations and needs, who is in the laboratory for a few years, injects something into this system that adds realism to everything the professional scientists do. When he, the military officer, recognizes—and he can be helped to do this—that his role is to

> present the formal face of the station to the outside, to relieve and protect the technical workers from much of the harassment emanating out of the District of Columbia, and to take care of most of the internal housekeeping functions, he usually finds that he can be very effective in exposing the laboratory people to the Navy's requirements and he can get very rapid and sympathetic responses.
>
> We have heard from enough scientists and engineers who have had experience in these particular laboratories to be quite sure that the constant reminders of conditions under *operational use* that come from living and working with the military officers in this way makes a world of difference in the end items.[57]

During Ashworth's NOTS command, he and McLean built on China Lake successes to achieve an unprecedented level of support from Washington. The station began a host of new projects, thus showing that it could follow its superb Sidewinder development with other innovations. Ashworth also understood the importance of introducing Sidewinder into the fleet with appropriate fanfare, and under his leadership China Lake hit the newsstands as never before. Within the station a smoothly functioning management team took its cue from the excellent examples of those at the top.[58]

Ashworth was also extraordinarily effective in dealing with the growing Ridgecrest-China Lake community and with Bakersfield, the Kern County seat 120 miles away. His three boys were students in the local schools, and he took a keen interest in community concerns, including conservation of the desert and construction of the China Lake All Faith Chapel, for which he placed the cornerstone on 28 October 1956.[59]

"I think the thing about Dick Ashworth is that he has such a very keen sense of how to deal with people," commented Capt. John I. Hardy, who served as NOTS experimental officer during Ashworth's tenure. "He had a lot of rapport with the scientific community and with the military operators, and he had a whale of a lot of common sense."[60]

Omens of Change

The shake-up at NOTS was soon followed by changes on the national scene that would dramatically affect the station and its work. The signal that reorganization was coming occurred in 1955 when the Hoover Commission was reconstituted, this time to look specifically at research and development. The commission's report reiterated some of the findings of the 1954 Riehlman Report that BuOrd laboratory managers liked to hear, but the Second Hoover Commission also delved into an area of discomfort for NOTS and its sister laboratories—that of in-house versus contracted technical work.

Pointing out that in fiscal 1954 the Navy expended about 40 percent of its appropriated R&D money on in-house work, the commission recommended transferring some of the operations of applied R&D and design to the civilian sector and concluded that, in the interest of "good management," a shift of new programs to the civilian sector should also be made, along with a "shrinkage of staff" in the military installations. The reference to shrinkage had an immediate demoralizing effect in the Navy laboratory community, especially since the in-house workload at NOTS and elsewhere was growing.

In February 1956 BuOrd completed a comprehensive realignment of its Research and Development Division. Instead of the former 10 loosely coordinated technical branches, just four units existed in the new organization. Each was administered by a weapons director who had full authority over his organization. That same year the Bureau of Aeronautics also concluded that stronger project management was needed and regrouped its class desks for aircraft, guided missiles, and aircraft nuclear propulsion under a weapon systems officer, as well as establishing program managers for six of the major weapons programs.[61]

One inescapable consideration was the December 1955 establishment of the Navy's Special Projects Office. Should this small, virtually autonomous organization be replicated elsewhere in the Navy? And what would the establishment of further independent offices mean to the bureau system? In January 1956 Chief of Naval Operations Arleigh Burke ordered Vice Admiral Ruthven E. Libby to examine the bureau system with a critical eye, particularly as it related to weapons development. After looking at several alternate approaches—including a merger of BuOrd and BuAer—the board decided that possible advantages were more than outweighed by the problems that would come with a massive organization. The Libby Board also rejected other alternatives—such as organization along warfare lines—ultimately concluding that none of the alternatives offered a decisive advantage over the existing system.

Discussion of the possibility of adopting more pared-down, ad hoc groups along the lines of SPO led to the conclusion that SPO had a "serious" impact on the authority of the bureaus that could prove untenable if more than a few such groups were organized. For this reason, the Libby Board recommended that the SPO organizational model be adopted only in exceptional circumstances.

The Libby Board's ultimate recommendation, formally established as Navy policy in August 1957, was to pursue a "lead bureau concept" Burke himself had proposed as early as 1955 as a way to avoid cognizance disputes between

BuAer and BuOrd. The idea was that a dominant bureau would assume overall direction of a specific weapon system, with that lead bureau also coordinating the work of the subordinate bureaus. The separate existence of the two bureaus would not continue much longer. Two years later the Navy would merge BuAer and BuOrd into the Bureau of Naval Weapons, an action consistent with a continuing trend toward centralization of authority.[62]

Until that merger, however, the relationship with BuOrd was one the station's leaders understood and participated in effectively. After Ashworth got orders to China Lake, he visited Bureau Chief Withington who expressed the view that "Sidewinder is pretty well finished, and the war is over, and there's not really very much going on." The perception that Sidewinder had reached the end of its development proved to be incorrect, since the missile is still a prime China Lake project. But NOTS' Central Staff had also plotted funding profiles for the station's major projects that had revealed that China Lake's immediate fiscal health was good, but that without new work, a precipitous decline lay ahead.

The view that the station needed to take on new projects was one that McLean was already acting on when Ashworth arrived at NOTS. The new

U.S. Navy photo LO 20495

Ashworth and McLean examining a Sidewinder missile, 31 July 1956.

skipper found McLean "a very modest and friendly man," someone whose perception of the way the work should be done matched Ashworth's own.

With Hack Wilson supporting McLean and with Executive Officer Capt. Frederick A. Chenault fulfilling the same sort of alter-ego role for Ashworth, "I don't see how you could have had a better combination of the top people that we had here in the laboratory," said Ashworth, adding that he experienced his time at NOTS as "the golden years of the place."[63]

Rocketeer, "12 Years of Progress," 8 November 1958

Captain Frederick A. Chenault, 1955

McLean rapidly convinced Ashworth and the others that the station needed a fresh approach to weapons planning. McLean believed that the country's experiences in Korea showed that an extended war with conventional weapons could be fought without escalating to nuclear weapons. That philosophy led him to emphasize conventional-weapon development as he planned for NOTS' future. He also worried about the national emphasis on nuclear weapons, pointing out that "there is no stopping point after you start using nuclear weapons."[64]

The Research Board had already begun a list of ideas for new projects, with suggestions solicited among the employees of all the technical departments.[65] In October McLean encapsulated these ideas in a memorandum with a conventional weapons focus unusual for its day. The station's best capability was "showing how to do things," the memo said, listing possible accomplishments as rockets with aluminum tubes, temperature-insensitive propellants, explosives of increased strength, water-reactive fuels, a tactically feasible guided missile, "a productive civilian scientific organization within a military structure," and more than 20 others.

Station leaders agreed that they would like to show how to build a beam-riding missile with one moving part, use metals for rocket propulsion, build an IR image converter, provide optical search at high altitude, double the specific impulse of rockets, make a sonic-beam-riding torpedo, launch missiles from underwater, provide shore-bombardment capability to submarines, and make torpedoes and missiles that would not require testing in the field before use.[66] Some of those projects had already begun, and others would soon start.

In January 1956 Ashworth and McLean took the list to Washington in the form of a "dog and pony show."[67] Over the following two years, the two men made several more presentations and kept communication channels open with influential friends in the defense community. Notable among the trips other station employees made for the same purpose was a meeting Bud Sewell and Frank Knemeyer attended with R&D officials of the three military services. "The Air Force said, 'We're perfectly happy with the conventional weapons we have,'" Sewell recalled. "And what they really meant was, 'We have no intention of hanging conventional weapons on any of our airplanes.'"[68]

McLean, Ashworth, and the others were ultimately successful in selling Washington officials on the idea of conventional-weapons work for NOTS—an amazing accomplishment considering the temper of the times. "As the result of Hiroshima and Nagasaki, the average military mind felt that conventional weapons were done," explained Peggy Rogers. "And henceforth and forever more, we'd play with nuclear. . . . There would be nothing that couldn't be cured by nuclear . . . that was the attitude, and most people didn't know anything about it, but they were sure it was going to."[69]

"At that time [NOTS' emphasis on conventional weapons] wasn't accepted very well, but it has become more accepted," McLean reflected years later. "I think it was very fortunate that we put a tremendous effort at NOTS onto the development of air launched weapons for limited warfare or we would have been even worse off."[70] China Lake's emphasis on the tools of limited warfare would strengthen our national defense during the era of the Vietnam conflict and beyond.

15

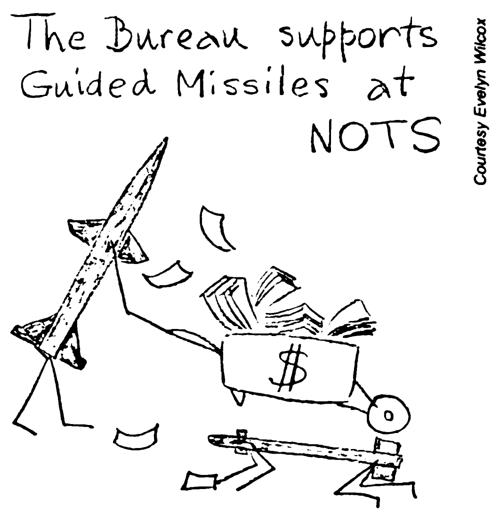
From Rocket to Missile

From the years 1953 to 1957, China Lake worked on its last major air-to-air rocket programs even as Sidewinder moved forward to fleet introduction. The new missile's success fed on innovations coming from the station's last rocket programs, even as the rockets themselves contributed directly to the defense of the nation.

After Sidewinder's first successful tests, the development team made unprecedented efforts to smooth the manufacturing process and simplify the preparation and troubleshooting process for the sailors who would have to perform under difficult and dangerous conditions.

Zuni—the Last of the Air-to-Air Rockets

Nobody realized when development of a new 5.0-inch rocket began that the sleek weapon Jim McDonald named after the Zuni tribe of the Southwest would be the last of China Lake's major air-to-air rocket development programs. Rockets had been central to NOTS work ever since the Navy established its desert laboratory in late 1943. Guided missiles were what Washington wanted developed in a new era, however, and Sidewinder pushed the station into making the transition. The funding shows the trend: in 1954 46.6 percent of the station's major weapons-program work was on rockets; by 1958 that percentage had declined to a mere five percent. In the meantime, funding for guided missiles had increased from 11 percent in 1952 to 27 percent in 1958.[1]



Wilcox cartoon depicting the NOTS funding situation after Sidewinder's initial successes.

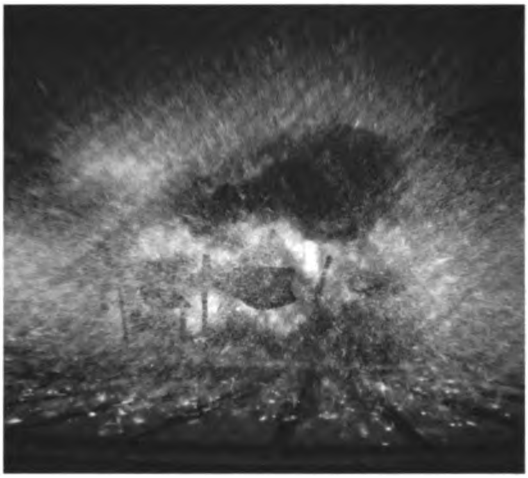
A triumphant missile rolls away a wheelbarrow of cash, while a rocket scrounges the leftovers.

The Zuni program began in 1953 as a result of a 1952 review of solid-propellant rocket development. When the study challenged rocketeers to state the design parameters for the ideal 5.0-inch aircraft rocket, McDonald stipulated a burning distance of 1,500 feet or less and a burnt velocity of at least 2,400 feet per second. Folding fins and a four-round streamlined package launcher would allow the Navy's workhorse AD-4 aircraft to carry 48 Zunis. The new rocket was basically a scaled-up Mighty Mouse, a VT-fuzed folding-fin rocket suitable for air-to-air or air-to-ground combat. The rocket's project engineer, Sid Shefler of the Engineering Department, designed much of the hardware. With BuOrd backing, Shefler and his team worked on two parallel Zuni efforts. Zuni II was a "thinking" rocket project in that it was intended as a continuous feasibility study of advanced rocket-design concepts. The first experimental Zuni I incorporated a piston-operated nozzle-fin assembly developed for the 5.0-Inch High-Performance Air-To-Air Rocket and used in both Mighty Mouse and Gimlet.[2] But because the assembly was costly to manufacture in the larger size, Zuni's developers decided to incorporate a more easily produced single-port blast-operated assembly.

The desire for simplicity and cost-effectiveness also motivated propellant design decisions. Zuni I's N-5 propellant had an internal-burning grain with an iron-cross-shaped hole running the length of its core. After this configuration resulted in erratic burning times at high temperatures, the team tried other internal-burning grain designs, including several types of stars. Each grain was coated with spirally wrapped ethylcellulose inhibitor, and each incorporated a ballistic modifier invented by Al Camp. Shefler and his team hoped that higher loading density and better performance could be achieved by burning the grain simultaneously from the inside out and the outside in.[3]

Steve Little, head of the Rocket Department's Aircraft Launcher Section, also asked Shefler to oversee development of the Aero 10A package launcher, soon renamed the LAU-10. Early concern about aircraft structural damage caused by ripple-firing four Zunis from the LAU-10 proved groundless when strain-gauge tests showed a rearward thrust of only about 10,000 pounds, "not enough to cause alarm among the aircraft design community," according to Little.[4]

As the Zuni development began, Gilbert "Gil" Fountain of the Rocket Department's Projects Division pondered how to improve the warhead to produce many fragments to destroy vehicles, aircraft, and industrial installations. Envisioning a warhead that would break into fragments before the weapon hit its intended target, Fountain studied British experiments with a grooved rubber explosive filler that made multiple shaped-charge grooves (cuts) inside the warhead case during detonation. After experiments with rubber, copper, aluminum, and several types of plastic, Fountain settled on a cellulose triacetate liner grooved in a waffle pattern. "There appears no reason why a grooved charge liner could not be included in many rocket and guided-missile warheads under development," he reported in December 1953.[5]


Courtesy U.S. Naval Museum of Armament and Technology

Controlled-fragmentation warhead test, Area R.

His waffle-grooved liner proved its effectiveness in field tests of the Mk 32 high-explosive antitank (HEAT) warhead, which carried 15 pounds of explosive for use against air-to-ground and air-to-air targets. The warhead was equipped with a proximity fuze or a point-detonating fuze, depending on intended use. Field tests routinely accomplished as many as 2,300 witness-plate perforations at a distance of 30 feet and showed that the fragments from one warhead could inflict fatal damage to a heavy bomber from a miss distance as great as 40 feet.


U.S. Navy photo LHL 121761

Continuous-rod warhead test at a remote arena. NOTS used the continuous-rod concept in both the Zuni rocket and the Sidewinder missile.

Another innovation used in Zuni was a continuous-rod or "flying watchband" warhead, which incorporated a bundle of interconnected steel rods that fanned out in a controlled pattern when they were activated by a proximity fuze. The warhead, invented at New Mexico Institute of Mining and Technology in Socorro, New Mexico, showed great promise in China Lake tests demonstrating that the rods, traveling at rocket velocity, could cut through aircraft structures.[6]

To enhance Zuni's effectiveness in a variety of tactical situations, station engineers developed other types of warheads, including one that incorporated a flare that could light an area of about two square miles from an altitude of 2,500 feet for more than a minute. Other developments included a mechanical backfuze, a point-detonating fuze, and an acceleration-arming fuze.[7]

By June 1953 work on Zuni was proceeding so well that the station considered the rocket nearly ready for experimental production. But the 2.75-inch FFAR and the redesigned Weapon A were also ready to enter the same phase. Fearing that pursuing all three weapons at once would overload the facilities, NOTS leaders decided to delay Zuni.[8] As a result, Zuni did not enter experimental production until mid-1955.

Evaluation by OPDEVFOR began in June 1956, but in the meantime, flameout problem seen with the first salvo firing of the 2.75-inch Mighty Mouse reappeared. The difficulty was that when a second rocket hit the combustible exhaust cloud from the first rocket, the nose of the second rocket would ignite, causing an explosion. The aircraft's jet engine would then inexplicably quit, and the pilot would have to dive, sometimes as much as 20,000 feet, to get the engine to restart. The first flight tests conducted at 45,000 feet at about Mach .6 had resulted in three engine flameouts—hair-raising situations for the pilots.[9]

In summer 1956 Bill McEwan, Alvin "Al" Gordon, Ruven Smith, and Charles Drew of the Chemistry Division worked extensively on the flameout problem. The chemists, all Ph.D.s, had Westinghouse modify one jet engine of a two-engine F2H Banshee aircraft, installing thermocouples and gas-sampling bottles at various strategic points within the engine and afterburner. "It cost $25,000 to put those test probes in the jet engine," said McEwan. "We had to swear on a stack of Bibles that the engine would be returned to pristine condition."

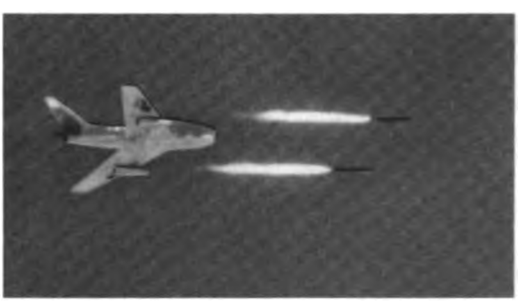
The chemists discovered that the thermal wave of a rocket's exhaust gases stalled out the engine's compressor blades, momentarily cutting off the air supply to the burners. When the aircraft's fuel mixture became too rich, the afterburner fire went out. For safety reasons, the only solution was to get the rocket exhaust gases away from the air intakes of the jet engines. "This problem came back every time a new aircraft was designed," McEwan said. "The airframe engineers brought the rockets in closer to the body to reduce the torque on the wings only to be reminded by the rocket scientists that they couldn't do that and keep the jet engines burning."[10]

During Zuni's OPDEVFOR evaluation, VX-3 and NOTS pilots reported good dispersion characteristics. The air-to-ground evaluation reached its successful conclusion by the end of 1956, with the development force recommending that the fleet accept Zuni for air-to-ground use. With this hurdle cleared, pilot production of 10,000 Zunis began in early 1957.[11]

On 1 March 1957, Zuni shed its wraps of secrecy in what would ordinarily have been a gratifying way, with more than 125 members of the national media in the stands at Armitage Field to witness the first public firing. But because Sidewinder had its first public demonstration at the same time, most of the newsmen gave Zuni short shrift. It didn't help Zuni's case, either, that the ebullient Lieutenant Commander Glenn A. Tierney (later a commander), head of Guided Missile Unit (GMU) 61 and Sidewinder's main "shooter," was narrating the show. The reactions of Irving Stone of *Aviation Week and Space Technology* were typical—a rapturous article about Sidewinder with a concluding comment that "other demonstrations at NOTS included rocket firings, bombing techniques, rocket sled run, tow target maneuvers and Terrier firing."[12]

Only Marvin Miles, aviation editor for the *Los Angeles Times*, made more than passing mention of Zuni. After reading about Sidewinder's public introduction on the front page, Los Angeles readers had to turn to page 21 to learn that "Sidewinder was not the only new development shown at this vital naval test station today." Miles described the new rocket in glowing terms:

> In a demonstration attack from a diving FJ-4 Fury jet fighter, eight Zunis were ripple-fired in units of two to slam perfectly across a ground target as the blast from their supersonic speed reached across the desert. . . . [Zuni's] speed is astounding—greater than that of the Sidewinder—and it blasts into a target with impact velocity that is terrifying if one considers himself on the receiving end.[13]




Zuni test sequence, 25 August 1959.

Rockets fired from an FJ4 aircraft knock a target drone out of the sky in flames.

Contractor's automated line for production of Zuni rockets.

On Armed Forces Day, 18 May 1957, a big show at NAF featured eight Zunis fired in pairs at one-second intervals to straddle a ground target. Describing Zuni as "effective for both air-to-ground and air-to-air attacks," the *Rocketeer* told readers that appropriate targets for the new rocket would include motor convoys, tanks, gun emplacements, and heavy bombers, which, the article said Zuni would bring down "in a cloud of warhead fragments." Again, however, Sidewinder stole the show. This time the irrepressible Tierney took Miles up in the aircraft with him and let him actually push the pickle. Needless to say, Miles' next article focused on Sidewinder.[14]

By late 1958, production of 45,000 Zunis had begun, and fleet introduction was scheduled for fall 1959. The idea was to equip Atlantic and Pacific Fleet carriers with the rocket by 1960.[15] Zuni's continuous-rod warhead would become a success—but in Sidewinder, not in Zuni. Although the air-to-air version of Zuni was canceled, the air-to-ground version would prove useful in Vietnam and other conflicts to this day.

Gimlet—Winning Over Washington Doubters

Even as the station worked on the medium-caliber Zuni, BuOrd continued its support of a small-caliber folding-fin rocket to be used against all classes of aircraft. By early 1954 the 2.0-inch Gimlet was making great progress, with experimental production of 3,000 motors under way. At the same time, the Air Force, under contract with Thiokol Corporation, was developing its own two-inch rocket, the T-214 (with the T signifying Thiokol). While the Air

Force criticized Gimlet for lacking a self-destruct mechanism, China Lake rocketeers expressed their dislike of the T-214, in particular its fins, which often jammed at launch and which caused the rocket to spin after launch, thus making prediction of a dispersion pattern extremely difficult.[16]

An innocuous statement in the station report on major accomplishments of the year noted that "a detailed competitive review with other 2.0-inch rockets is scheduled for March 1954."[17] The review, to be held in Washington, D.C., would pit Gimlet against the T-214, with the judges representatives from all three services and the assistant secretary of defense for R&D.[18]

Pat Patton was to give the Gimlet presentation—with help from Ellis and others in a sizable group of NOTS representatives who traveled east by train, writing Patton's speech for him as they went. Patton realized with a sinking feeling as the miles rolled by that the Gimlet presentation-by-committee was becoming "more a publicity speech for China Lake than it was a discussion of the niceties of the Gimlet." Nevertheless, he dutifully gave a dry run to Navy dignitaries in one of the bureau's temporary buildings on Constitution Avenue. After reading his presentation to a gold-braid-filled room, Patton was rewarded with "a thundering silence" from his audience.

The experience convinced the China Lakers that another approach was needed. Patton spent the night in his hotel room writing a new speech. He recalled that at the big meeting the next day, the Air Force representative brought a lengthy, detailed presentation to a reluctant halt only after his superior officer signaled him to stop. Then it was Patton's turn. He remembered:

> The T-214 . . . brought in its firing current through the tail fins, running a pair of wires up the grain to the igniter, which was in the front end just behind the warhead. In the Gimlet, we had developed a forward contact band with infinitesimal leads to the igniter. The contact band was up at the junctions to the warhead and the motor, and so we had no ejecta except four tiny aluminum plugs for the four nozzles. So at the appropriate point in my speech, I said, 'Which would you rather have being ejected into your windscreen? This?' And I brought out of my pocket all of this wire and this igniter. 'Or this?' And I reached into this pocket, and I had these four little aluminum plugs, which I *threw* at them.[19]

Patton later described his speech as a Pyrrhic victory, since Gimlet—still untried by the fleet—was canceled in 1957, largely as a result of progress on Sidewinder. The immediate upshot was that Gimlet had the go-ahead for pilot production—but only after warhead and fuze redesign to meet additional requirements, a process McLean described as "quite a struggle."[20] Patton named it Project Lamb in reference to the Ram project, "only it wasn't going to be quite as Ram-ish as Ram."[21] The time allowed for improvements—a mere two months—made for a Ram-ish schedule, however.

Bob Olsen and his Fuze Branch had the task of developing a self-destruct mechanism, and, after what Patton described as "a lot of head-scratching," Olsen came up with an appropriate device, installed at the base of the warhead and ignited by the motor igniter. With the mechanism's worth proved in a series of tests on the ranges, Gimlet was ready for a flyoff with the T-214—an event that turned out to be far from the glorious vindication the NOTS team had hoped it would be. In Patton's words:

> [W]e had been bragging about the fact that our double-based propellant was absolutely smokeless. . . . And the T-214 smoked like your grandfather. It put out a great stream of black smoke. We said, 'Oh, boy, that's terrible! Giving away the location of the launching aircraft and everybody knows that a rocket's been launched,' and all that sort of thing. Well, we were called upon to eat those words . . . What we discovered was that at night the T-214 was absolutely invisible. There was nothing you could see. Well, our Gimlet laid out a trail of sparks that was spectacular. So we sort of shut up about the smoking T-214 after that.[22]

Gimlet's nighttime trail of sparks was evidence of two lessons weapon developers learned the hard way: first, the importance of testing a product under conditions it might experience in combat; and second, the necessity of taking into account the ever-present possibility that a solution to one technical problem might cause another problem. The sparks came from a condition called unstable deflagration (more colorfully described by Patton as "the galloping heebie-jeebies"). What the NOTS team found out the hard way was that a modifier introduced to cure this condition not only destroyed the mesa effect of the propellant but also caused the sparks.

Although the fly-off caused red faces in China Lake, the long-term results were positive. In a discussion with Al Camp and Dr. Hans K. Haussmann, McEwan suggested that the exhaust-gas combustion was a chain reaction that might be quenched by potassium salts. Back in World War I, he pointed out, small bags of potassium sulfate had been put in the cannon powder to reduce the telltale flash of firing artillery at night. Since McEwan's studies of the mechanism and burning rates of mesa propellants had shown that stabilizing material incorporated in the propellant destroyed the mesa effect, some other means would have to be found to introduce the potassium sulfate.

With this information in hand, Camp and Haussmann designed and patented an improved resonance rod coated with potassium salts in a plastic base. That improvement was immediately incorporated in Gimlet, as well as in the 2.75-inch FFAR, where it solved what had been a serious problem with afterburning of the rocket exhaust. Once again the worth of backing up development with on-site research had been demonstrated.[23]

The self-destruct mechanisms the Gimlet and T-214 fly-off had been designed to test functioned well for both rockets and consequently were no longer a concern. But further repercussions from the rivalry surfaced in early March 1955, when Secretary of Defense Wilson wanted the two rockets to be developed "on converging courses." The Navy then proposed a modification, with the T-214 tail tacked onto Gimlet to make what became known as T-Gimlet. Wilson found this compromise acceptable and approved pilot production of both G-Gimlet (the original NOTS version) and T-Gimlet, with approximately $5 million to be split between the two programs.[24]

Excellent progress was also made on the Gimlet motors, with more than 2,100 of them undergoing test by April 1954. By that June G-Gimlet entered pilot production of 15,000 units, and by July 1956 pilot production of the rocket's igniter was completed and loading at the Naval Ammunition Depot at Shumaker, Arkansas, had begun. But Gimlet's days were numbered.

With the dawn of the missile age, weapons planners saw little need for new rocket developments. In early 1957 NOTS stopped all effort on G-Gimlet, with only the first 15,000 pilot-production rockets having been built. Termination of the T-Gimlet version followed that October.[25] Gimlet's developers were unsuccessful in attempts to apply some of the program's innovations to the 2.75-inch Mighty Mouse, no doubt partly because of the feeling that the 2.75 scarcely needed fixing, having already been highly successful in combat.[26]

Thus Gimlet became a casualty of the military services' transition from rockets to missiles. The good engineering work that went into Gimlet was not wasted, however, since improved production processes devised for the rocket were later modified for Sidewinder production.[27]

Other Advances in Rocketry

During the last years of the NOTS rocket program, innovative work also proceeded on the 5.0-Inch Liquid Propellant Aircraft Rocket (LAR). Patton, who inherited liquid-propellant programs in 1954 when he became head of the Rocket Development Department, praised LAR for its elegant simplicity. "Everything on that served about three different purposes," he said later. "It was wonderfully simple, and yet it accomplished the problem of mixing two propellants, keeping them safely separated, and yet mixing them at the proper time and igniting them."[28]

By 1954 the basic design principles had been established, and the station let a contract with North American Aviation to manufacture 205 Model 501C LAR rockets, with engineering improvements scheduled to continue even as the rockets came off the production line. The 501C had numerous internal improvements and was equipped with tangential folding fins that allowed it to be stored in a small space. In temperature-controlled tests, the model performed well in moderate to high ambient temperatures, but malfunctioned at temperatures below freezing (such as in high-flying aircraft). The problem appeared to be in the fuel valving. Ingenious as it was, LAR's cutter valve, which allowed the highly corrosive propellants to mix only as the rocket was fired, would have to be rethought. Tony Ozanich and his team weighed the relative costs of redesign or modification. Preliminary contractor estimates on production of 1,000 rockets incorporating the cutter valve showed a high unit cost. A further valve modification probably meant serious compromises that would make the rocket more complicated and costly. Ozanich and his group decided to rethink the design of the entire rocket.

The team was confident that within the year or so before experimental production began, a design could be developed that would allow low-cost manufacture and meet handling and performance requirements. Accordingly, work began in early March 1954 on LAR Model 502, with the goal of a 1,600-unit experimental production program.[29] Like previous versions, Model 502 featured folding fins, concentric propellant tanks, and a solid-propellant gas generator. The Mark 25 Mod 2 warhead chosen for the experimental round had two advantages—low cost and the ability to simulate the Zuni warhead. The plan was that LAR and Zuni would use the same warhead model.

New to Model 502 was a clever, yet simple, arrangement to replace the cutter mechanism. Gas emitted by the solid-propellant grain flowed through the rocket into a ballonet, which expanded as it inflated, thus causing intense pressure on the fuel in a concentric tank surrounding the ballonet. When this pressure reached 1,800 pounds per square inch, a fuel rupture ring would break, and the rocket's inner shell would move back to expose an opening through which the fuel and oxidizer could mingle. The combined propellant would then be injected into the combustion chamber to ignite spontaneously. This arrangement had the advantage of allowing LAR to launch before the propellants and hot gases mixed.

The development team designed additional reliability and safety into the Model 502, even at the expense of more weight. The team reasoned that if the rocket were so durable that leaks could not develop under even the worst handling conditions, the type of liquid fuel used would be relatively unimportant from a safety standpoint. The maximum drop height specified was 40 feet, the distance a rocket could conceivably fall in an aircraft carrier's ammunition elevator. Tests showed that LAR was tough enough to take the punishment. Test rockets fell nozzle down through first 20 and then 40 feet without leakage or damage to the valving. A key feature of this remarkable ruggedness was the rupture ring, designed to rupture only when it encountered pressure six times that it would experience in a 40-foot fall.

In test firings of LAR's previous incarnation, ballisticians had found the rocket's performance difficult to predict because of large variations in starting temperature—a problem that had plagued other rockets and that NOTS had partially solved through development of mesa-burning propellants. The new model's solid-propellant gas-generator grain was formulated from X-11, a mesa propellant tailor-made for LAR.

U.S. Navy photo, courtesy Felice Plain Mueller

John Pearson.

One of the most significant improvements to LAR's hydraulic and mechanical devices was the welding that joined the tube to the warhead. A new low-penetration welding technique developed by John Pearson, head of the Propellants and Explosives Department's Warhead Research Branch, used water chilling in the area of heat application and a rapid rate of bead deposition to fuse aluminum alloys that were previously thought to be unweldable. Pearson's process was rapid and easily reproduced. It also required relatively inexpensive equipment.[30]

Other simplifications involved the injector, the forward valving, the combustion chamber, and the gas generator tube. The savings were nothing short of spectacular: the estimated cost for manufacture of the Model 502 rocket was less than a third that of Model 501C.

The station completed all improvements by August 1954 and delivered the first test rockets the following November. Initial tests showed success. The propulsion unit of the Model 502 was 10 inches shorter and contained less propellant than the previous model, yet because it had shed 17 pounds, it was capable of essentially the same burnt velocity. The rocket flew successfully from ground launching and was statically fired successfully at temperatures well below freezing. The station took delivery of the first experimental-production rockets in August 1955. The decision to redesign had paid off.[31]

As with Gimlet, LAR had a short life. The rocket was canceled in 1958 before it could enter the fleet. But lessons learned from LAR were later applied to similar systems throughout the country. LAR established the advantages of using hypergolic propellants in rocket systems with short burn times and high thrust; it also showed that fluid-flow systems could be designed to allow safe shipboard storage. In this regard, the program developed and tested several promising valving systems, including one later used in the Bullpup missile.[32]

Notable among NOTS' many other successes in rocketry was the 2.75-inch FFAR, Mighty Mouse. The advent of Sidewinder and other guided missiles ensured that Mighty Mouse would not be used for the air-to-air application for which it was originally designed. Nevertheless, its usefulness as an air-to-ground "fly swatter" continued. By mid-decade versions of all Air Force interceptor jets carried 2.75-inch FFARs in varying numbers from 24 to 104 as prime armament against hostile aircraft.[33]

Mighty Mouse, which became a valuable component of the ground-attack arsenals for all three military services, was the first U.S. rocket since World War II to achieve mass production in the millions. Three million rockets rolled off the assembly lines in fiscal years 1953 and 1954 alone. In 1965, with existing stores depleted, the Army ordered up a million. By the end of the century, more than 20 million rockets had been produced, with a remarkably low malfunction rate of less than one in 10,000. China Lakers were proud of the rocket's success as "the most-fired non-bullet ordnance in history." That success also strengthened BuOrd's confidence that NOTS could handle major development programs.[34]

At the heart of this and other successes in rocketry at China Lake is the concept of "cradle-to-grave" development—the facilities and teamwork that allowed the rocketeers to come up with a concept, create the necessary hardware, test and refine the hardware until the idea worked, then ensure reliability all the way through pilot production and fleet introduction. And even as China Lake innovators tested their last rockets on NOTS ranges, that cradle-to-grave approach was thriving in the Sidewinder development.

BuOrd Evaluation of Sidewinder

The Sidewinder team was still gratefully accepting innovations developed for the last rockets. In the missile's project offices, however, the emphasis shifted to preparing for the fleet introduction Howie Wilcox had so confidently predicted for January 1956. Normally both Technical Evaluation (TECHEVAL) and Operational Evaluation (OPEVAL) must be completed before approval is obtained for production, but Sidewinder was so promising that the production go-ahead bypassed these steps. Production began in early 1954, and NOTS received the first production Sidewinder in April 1955.

OPEVAL would still be needed before fleet introduction, but first BuOrd wanted an independent test program at NOTS, a rigorous review ending in a definite recommendation on whether the missile was ready for fleet evaluation. In an April 1955 memorandum, Re9 noted that the weapon was so new that criteria did not exist for it to be judged against and asked NOTS to provide "a factual determination of what the performance characteristics and service capabilities actually are, including exploration of the maximum capability limits, rather than whether certain undefinable criteria are met."[35]

McLean delegated Hack Wilson to coordinate the review, with direct evaluation responsibility assigned to the Test Department. Ted Toporeck established a six-month schedule and set up a Sidewinder Evaluation Committee chaired by William E. Vore. In August 1955 the committee began studying the missile's performance, quality, checkout equipment and procedures, relationship to its launching aircraft, assembly and handling, stowage, and safety. Fleet personnel were itching to get their hands on the missile, and the results from the NOTS evaluations looked excellent.

As part of the BuOrd evaluation, GMU-61 pilots began developmental test firings in July 1955. On 8 July Tierney made an unauthorized experiment over the China Lake north strafing range, nosing his F9F-8 Cougar into a steep dive at full power, then firing his wingtip Sidewinder after an HVAR from his other wing. The unflappable Ashworth's main comment on the uncleared flight was the recommendation that Tierney needed to mend fences with the range scheduling and safety folks. More significantly, the event helped reassure the aviation community that the sleek missile was reliable at supersonic launching speeds. By the end of the year, 88 shots, some of them against supersonic aircraft, had demonstrated Sidewinder's promise again and again.[36]

A few nagging problems, however, remained to be solved. Wilcox assigned Amlie to simulate on the REAC the missile's tendency to spiral during flight. As Amlie recalled:

> I fired up my computer model. . . . The bearing [of the ball gyro] was beautifully made, and I could duplicate the results if I assumed there was 26-thousandths of an inch of slop in the bearing, but there wasn't even a 10-thousandth. . . . I went to Dr. Haseltine, and he sort of explained it to me. So we started building

> a gimbal, and we knew McLean would hate it because it added more parts, but we had to do it.[37]

Amlie then turned to Don Stewart, who designed a mechanism referred to as the "inside-out, top-hat, gimbaled joint" or the "Scotch yoke," the heart of a device intended to replace the ball gyro of which McLean had been so proud. With the spherical bearing, the coupling between the seeker and the airframe had necessitated a limit to the missile's maneuverability during post-launch acceleration. The airframe-seeker coupling had also sometimes caused the gyro to precess off the target. Since the internal gimbal eliminated the need for this coupling, the missile could receive active guidance earlier, and missile flight would become more stable.[38]

Flight tests of Sidewinders incorporating Stewart's design rapidly proved the new gyro's worth, but team members were reluctant to tell McLean that his elegantly simple ball gyro would have to be replaced by a more conventional device that was more complex. Stewart put together a display for presentation to McLean. Cartwright remembered looking at the two devices side by side on the display board—the new one with about eight parts and the original one with only two—and remarking incredulously, "You're going to show that to Bill and tell him it's *improved*?"[39]

What Cartwright, Stewart, and the rest of the team didn't realize was that McLean had already spotted the problem of spiraling in the flight-test data. When LaBerge went to the technical director's office in the Administration Building to discuss the problem, McLean opened the conversation with a rueful shake of his head. "I've looked at the data," he said, "and we've got to have a new gimbal." Pulling Stewart's gimbal out of his pocket, LaBerge asked, "Like this, Bill?"

McLean was delighted—as was the Sidewinder team, who, according to Amlie, cherished the gimbal development and presentation to McLean as "the only time we ever got ahead of him."[40]

Sidewinder to Foldwinder

Even before Sidewinder's first successful flights, the team had begun to look ahead to improving and modifying the basic design. In March 1954, when Sidewinder 1 was frozen for production, the time seemed ripe to approach BuOrd with new ideas.[41] McLean incorporated three of these ideas in a memorandum for the bureau. Pointing to the success of the Sidewinder program in "incorporating in one missile all of the basic developments required to make guided missiles a tactical reality," McLean enumerated "new and novel solutions of essentially all of the basic problems involved in guided missile design." The next step, he said, was to plan the adaptation of Sidewinder technology "to a wide range of tactical problems as well as to use its components to improve other missiles." Two of his suggestions were to substitute a radar head for Sidewinder's infrared head and to use radar for midcourse guidance, ideas that would soon be exploited in the missile's SARAH (Semi-Active Radar Alternate Head) and IRAH (Infrared Alternate Head) versions. The third idea was for Foldwinder, a folding-wing Sidewinder that could be internally stored in the F4D Skyray and other supersonic aircraft.[42]

The McLean memo met with mixed reactions in Washington. A CNO decision to introduce supersonic aircraft (F8U, F9F-9, and F4D) to the fleet by late 1957 had increased the emphasis on development of suitable air-to-air ordnance. Consequently, although officials in Re were eager to keep NOTS focused on the main Sidewinder effort, BuOrd agreed that work on Foldwinder was within the scope of the program and "should therefore be pursued on such a time scale that it would be available concurrently with the advent of supersonic aircraft in the fleet." The bureau cautioned, however, that the development should not interfere with Sidewinder's fleet introduction.[43]

To help keep the focus on Sidewinder, Wilcox suggested that Avion, with its extensive Sidewinder experience, become Foldwinder's prime contractor. He also proposed that the missile include a small Avion-developed A-head seeker, a longer-burning gas-generating grain, an improved torque-balance control servo, a shorter rocket motor, and possibly a continuous-rod warhead. The preliminary design and development work, to be done at NOTS, would take a back seat to the main Sidewinder endeavor. Wilcox suggested a short 18 months as the time necessary for development, with the first production Foldwinders available for engineering evaluation by about March 1957 and fleet release projected for 1958.

Three months later the bureau turned down the separate program and urged pursuit of the new missile as part of the main Sidewinder effort. Nor would additional funding be available for Foldwinder. The memo described the bureau chief as gratified with Sidewinder's excellent performance in 1954, when about half of the 50 flight tests had demonstrated lethal-range homing. Still, Foldwinder would have to go through a study phase before BuOrd would issue a formal Operational Requirement. The bureau also cautioned that the name Foldwinder should not be used because it sounded like a new program rather than a Sidewinder modification.[44] Foldwinder officially became Sidewinder 1B. But the NOTS mavericks kept the original name for use at home.

By spring 1956 both folding-fin and folding-wing models had been fabricated. Bench tests were in process, and limited tests had been conducted on SNORT. The plan was that the first aircraft to carry Sidewinder 1B internally would be the F8U-1, and NOTS people were working closely with Chance Vought Aircraft Company on what Newt Ward described as "mutual problems involving getting SIDEWINDER 'into' and 'out of' the aircraft."[45]

Tests conducted at SNORT to try out Mike Kamimoto's folding-wing designs brought out tough mechanical problems. Launching into the airstream caused aerodynamic force on the wing that made it difficult to open and lock. Furthermore, launching the missile from inside a fuel-filled aircraft would be difficult and dangerous. After testing several designs, Jagiello, Kamimoto, and their helpers reluctantly concluded that Foldwinder's time had not yet come. Achieving forward launch from an internal bay at supersonic speeds appeared impossible. Buffeting air currents and vibrations at launch were likely to damage both aircraft and missile.

The folding-wing version of Sidewinder was discontinued in November 1957, although its seeker was later used on Redeye, the first of the shoulder-fired infrared seekers. "It was a good try, and I believe given enough time we could have been successful," Jagiello said.[46]

Helping Fleet Users

As Sidewinder's last major design flaws were fixed, the focus shifted to the task of helping the fleet get ready to use the missile. "In line with McLean's general philosophy, we visualized the poor bemittened sailor attempting to assemble the Sidewinder missile on the deck of a blacked-out and wildly tossing ship in the freezing spray of a wintry night," said Wilcox. "Consequently, our policy was that assembly of the missile should involve no loose screws or other small parts as well as no special tools."[47] Much work lay ahead before that policy could become a reality. Test sets, tools, containers, launchers, instructional films, and handbooks needed to be created, tested, and introduced to their fleet users.

Ed Swann, a significant contributor to Sidewinder from its early days, began redesigning the missile's several sections so that they would fit together in only the correct way, with screws in place and ready for tightening. The steps necessary to assemble Sidewinder in the field were reduced to a minimum number of simple mechanical operations, with each section of the missile to be shipped as a self-contained unit. Sailors would be able to accomplish final assembly with just one humble tool: an Allen wrench supplied with each

Sailors loading Sidewinder onto its launcher, 22 March 1956, during Operational Development Force tests.

missile package. Jagiello applied the same philosophy to a redesign of fin and wing assemblies.

Sturdy, inexpensive, and well-sealed shipping canisters that would fit economically on board existing ship magazines and stowage spaces also needed to be designed. James P. "Jim" Madden, head of the Engineering Department's Missile Support Branch, began inspecting ship magazines to ensure that the containers could be securely stowed and promptly retrieved on board the carriers. Madden was a demanding taskmaster, but as Wilcox commented, one who was "admirably focused on getting his job done with a minimum of wasted time and money."[48]

One area of emphasis was development of a simple shipboard test set. Swann recalled that with much waving of arms Wilcox expressed the view that "you really didn't want to go through the business of assembling all these things, taking them up, and putting them on the aircraft before you found out that it wasn't any good." Team members, who shared that viewpoint, worked to make test procedures as simple and sensible as possible.[49]

The first test set was an unwieldy box nicknamed the "washing machine" in honor of its size and weight. This gadget was to be tried out on *Randolph* (CVA-15). When Peter Nicol, a member of the Missile Support Branch, stipulated that the washing-machine test set would be moved between its test and stowage areas by means of the ship's dumbwaiter, one of *Randolph*'s officers exclaimed hotly that bulkheads would have to be cut to get the tester into the test area. No, Nicol calmly replied, the set would fit in the dumbwaiter. The officer insisted on wagering that it wouldn't, a guaranteed money-maker for Nicol, who had prudently measured both the test set and the dumbwaiter during a slow run-through at Norfolk Naval Shipyard. When the time came, the tester was loaded on the dumbwaiter without difficulty.[50]

The first trial shipboard assemblies showed that sailors could put a Sidewinder together in two minutes. Nicol sent word home of this accomplishment, only to learn that somebody in Washington had decided the requirement would be "one Sidewinder missile to the flight deck per minute, every minute." Nicol had a ready answer:

> I just wrote a nice letter back to him, and I said, 'Well, the Sidewinder assembly area calls for a minimum of two assembly stands, and with that second assembly stand, it allows us to provide a missile a minute.' And we never heard from the guy again.

Once a missile was properly assembled, tested, and installed on its launcher, much of its success depended on the person the Sidewinder handbook identified as "one of the best airborne computers possible—the pilot."[51] The 24-page handbook incorporated lessons GMU-61 pilots had learned the hard way. Published in April 1954, the same month McLean became technical director, the handbook described operating procedures of remarkable simplicity:

> After take-off, pilot switches SIDEWINDER missile on to continuous standby aircraft power for instant firing. Audible missile signal tone to pilot's earphones via selector switch continuously indicates correct seeker operation and furnishes all required missile readiness information before firing. . . . In combat, pilot places fixed aircraft sight on target (thereby aiming boresighted missiles at target), hears target signal tone from missile in earphones, fires missile. . . . Pilot has no operational limitations on aircraft flight freedom after firing.[52]

China Lake archives

Sidewinder pilots' handbook, first published in December 1955.

High Noon at Holloman

As with every successful team project, some Sidewinder stories have become larger than life. Of all the Sidewinder tales, those known as the "Holloman shoot-offs" are among the most colorful. The shoot-offs occurred in summer 1955 at Holloman Air Force Base, White Sands, New Mexico, where tests were scheduled to show the Air Force what the Navy's new missile could do. Riding on the outcome was acceptance of Sidewinder into the Air Force arsenal.

Wilcox and others at NOTS were convinced that the Air Force had at least as much need for Sidewinder as did the Navy, a need stemming from the preeminent role of the air service in defending the continental U.S. against enemy bombers.[53] Air Force leaders favored the semiactive-radar-guided version of Falcon, under development by Hughes Aircraft Company. Both missile projects involved prominent members of the Caltech fraternity (McLean for Sidewinder and Simon Ramo for Falcon) and both had begun at around the same time, but they followed divergent courses thereafter. While Sidewinder flourished as a relatively small in-house effort, Falcon had become a well-funded problem-plagued program, to which Hughes devoted vast material resources and labor. "The Falcon was essentially pursued from the point of view of starting with an airplane and taking the pilot out," Wilcox said.[54]

Ironically, the Air Force had offered generous funding support for Sidewinder in 1952, only to have NOTS turn the money down on the grounds that the development was not sufficiently advanced to justify the proposed level of expenditure.[55] In 1955 the Air Force pilot community was eager to try out the Navy's promising missile, especially after a high-ranking officer showed up at China Lake to test LaBerge's claim that "We can teach you all you need to know about firing Sidewinder in 20 minutes." The visitor apparently fired two rounds, with one of them knocking down a drone. LaBerge recalled that the officer spread the word among Air Force pilots that "Hey, this works. It *is* simple."[56]

In an attempt to spread that enthusiasm to Air Force decision-makers, Wilcox, Sidewinder's best salesman, put a hefty reel of test shots under his arm and set off on a round of visits. His first stop was the Strategic Air Command headquarters in Colorado Springs. "I showed them lots of missile shots," Wilcox said, "and, man, they were impressed!" Next he visited Continental Air Defense Command headquarters in Omaha. Once again, his spectacular test footage enthralled a roomful of Air Force brass. But the requirements officer wasn't buying. He pointed out that the Air Force missile requirements paper spelled out the need for an all-weather missile. Falcon was all-weather, he said, but Sidewinder wasn't. Wilcox remembered arguing at length for Sidewinder's merits, pointing out that the radar-guided Falcon could not truly operate in all weather. His listener remained adamant: the Air Force had a course and would stick to it.

Feeling "totally defeated," Wilcox returned home and reported, "The Air Force is not buying."[57] McLean, however, was not discouraged. He turned to his mentor and teacher, Dr. Charles C. Lauritsen. As the discoverer of the site for NOTS and the boss of its wartime rocket programs, Lauritsen had a special place in his heart for China Lake. (Indeed, he was the NOTS Advisory Board member with the longest tenure, serving continuously on that group from its 1949 establishment until his death in 1968.) Lauritsen also had a profound, if low-key, influence over the course of America's postwar weapon research and development. "Few men have been as successful in pointing the direction that events should take, and then seeing to it the required events did indeed take place," observed Ellis.[58]

Lauritsen agreed to use his influence to help China Lake. His ties with Air Force decision-makers had recently been reinforced through his membership in the Strategic Missiles Evaluation Committee headed by Dr. John von Neumann.[59] This influential committee had been handpicked by Trevor Gardner, special assistant to the Secretary of the Air Force, who was pressing for expanded missile programs in an era of cutbacks. Gardner had been Lauritsen's student at Caltech as well as the top GT&R official at NOTS Pasadena and had already favorably reviewed Sidewinder during a 1953 study of U.S. guided-missile programs. When Lauritsen approached Gardner, he agreed to listen again to China Lake's case.

As a result, McLean called Wilcox before dawn one Sunday, asking for his company on an immediate trip to Pasadena. Wilcox remembered shaving and dressing in something like 15 minutes. By 9 a.m. the two China Lakers were sharing a booth in a Colorado Boulevard cafe with Gardner and Lauritsen. "Trevor Gardner threw all kinds of detailed questions at McLean and me," Wilcox recalled. "We answered these questions as best we could—I think quite well—and at the end of the breakfast, Trevor Gardner said, 'Well, all right, the Air Force has got to have this missile. Now the question is how to get it. . . . We'll have to have you actually come down and demonstrate that you can hit targets at an Air Force base.'" He then asked, "Can you do that?" Yes, the China Lakers assured him, they could.[60]

After Gardner paved the way for a 12 June 1955 comparison, the two top officers of the GMU-61 test unit, Tierney and Lieutenant Rufo W. Robinson, flew a "trusty old highly subsonic F3D" from China Lake to Holloman Air Force Base, hoping to demonstrate that the Navy's new missile could find its target even looking down toward blindingly white sand.[61] The Holloman facility near Alamogordo, New Mexico, had been selected as the site for the shoot-off because that was where the Falcon field-test activities and ready missiles were located. The NOTS ground-support team included Mickie Benton, Donald "Don" Grasing, and Robert A. "Bob" Blaise, plus a couple of ordnancemen. Rod McClung and Joe Pray followed along with telemetry equipment in the Sidewinder test truck.[62]

Since the guidance unit and the telemetry unit were both thoroughly checked at China Lake, little test equipment needed to be hauled to Holloman. "I don't think we had much with us other than maybe a flashlight . . . and a little console . . . to do a final check on the guidance unit to at least see that it was turning up and would track," Benton recalled. Upon arrival, the NOTS group asked where they could set up operations, and their Air Force hosts directed them to a massive building, "chockablock," according to Wilcox, "with a most impressive number of Hughes engineers and technicians milling about their many Falcon missiles, vast arrays of test equipment, [and] several Falcon launching aircraft." Benton also remembered that the preparation facilities needed by the two missiles presented quite a contrast:

> The Air Force gave us . . . one corner of a hangar at Holloman, and we had a little work bench over there. . . . There wasn't much interest in our presence. We were right next to one of the AIM-4 [Falcon] flight checkout buildings, an enormous building. . . . We threw our checkout equipment together out there in the hangar on this one workbench, gave the guidance unit to the ordnancemen, they went out and hung the missile on the airplane.

The China Lake contingent readied Sidewinder for firing in record time. The authorities at Holloman had agreed that two QF-80 drones would be used as targets, one each for Sidewinder and Falcon. Drone targets were difficult to come by, and these small, straight-wing, Korean War-era jets were precious assets. Benton recalled that the Air Force participants approached the test with the attitude that the Navy shooters weren't likely to hit the target, so a cooperative gesture could be made at little expense.[63]

Since Sidewinder was the first missile ready to fire, the Air Force agreed that NOTS would have the first shot—a 15-degree dive at high noon down toward the brilliant sand. "Other than looking at the sun, there's probably not a hotter IR background to fire an infrared-seeking missile into," Tierney commented, adding, however, that the NOTS team was fairly confident that the Sidewinder would home on a point target like a jet engine against an equally strong IR background with a one-to-one signal-to-noise ratio. "But I don't think we would have bet too much on the first shot," he said.

Tierney and Robinson took off as scheduled, and precisely at noon Robinson hit the button to send Sidewinder streaking toward its drone target. As the test proceeded, the NOTS contingent gazed intently skyward from the side of the Holloman hangar. A radio to monitor the countdown and Benton's binoculars were all the watchers had to keep track of what was going on overhead until Sidewinder hit its target and the drone erupted in flames. It was "quite a show," Benton said. Since few of the Air Force participants had expected the missile to succeed, only a few Holloman personnel were there to witness the event.[64]

Now Falcon would have a turn. The Holloman flight crew took off as planned, but that was the only part of the flight that went as scheduled. To safeguard the expensive Falcon against inadvertent launch, the Air Force had stipulated a series of firing-circuit interlocks that prevented the missile from leaving its host aircraft unless conditions were perfect. The Air Force shooters made run after run on the drone—to no avail. The conditions never became perfect, so the bird stayed stubbornly on its launcher. Several days passed. According to Wilcox,

> [E]ventually the generals wanted to give Sidewinder another chance. But we didn't have any more drones. Well, they said, "Give them a chance against the Falcon drone." But the Falcon people said, "Look out, now, don't give them our drone, we won't have any drone." "Oh, they won't hit it, go ahead and let them try."[65]

With that authorization, Tierney and Robinson took off again. This time Tierney pushed the pickle button. The shot, he said, was "a piece of cake," about as easy as sitting in an office and shooting out an overhead electric light with a shotgun. "The second one took it right in the pipe, which was really spectacular, really spectacular," he said.[66]

Project Red Hot—Missile vs. Rocket

All right, Air Force brass conceded, Sidewinder works well at low altitudes, but what about high altitudes? Show us that Sidewinder can perform at altitudes of 60,000 to 70,000 feet, and we'll buy the missile. The station eagerly agreed to another shoot-off, this time a high-altitude test of Sidewinder's capabilities that would be so conclusive that the Air Force would finally agree to leave its trouble-plagued Falcon in the garage and use the Navy's new missile instead. The problem, though, was that no target drone existed that could operate at the stipulated altitudes. Undeterred, the China Lakers proposed launching target rockets from the host aircraft. The idea was that a test pilot flying at a 40,000-foot altitude would launch a rocket from one wing, then four seconds later fire Sidewinder from the other wing. The missile would then home on its tiny target, destroying the rocket at around 70,000 feet. Air Force jaws dropped at this proposal. According to Wilcox, "The idea of a missile firing against a rocket was considered very, very bizarre—in fact, impossible. However, we had in fact been shooting against target rockets for a couple of years, so we felt quite confident that we knew what we were doing."[67]

The Air Force, unable to offer a better alternative, agreed to the idea. Consequently, in late August 1955 a small group of Sidewinder people again climbed on board a cargo plane and flew to New Mexico, taking with them six missiles, a couple of launchers, and a handful of mundane hand tools—pliers, hammers, soldering irons. The Air Force named the shoot-off "Project Red Hot" and assigned three aircraft and a photo chase plane, plus aircrews, to the endeavor. The ground support would be provided by NOTS.[68]

Memories differ about who visited Holloman for this second shoot-off, but the inexhaustible Chuck Smith was there, as were Bob Blaise representing the Test Department and probably a colorful chief petty officer from GMU-61 named John "Mac" McManus. "Incidentally, not all of the selling was done in the air," Smith later commented. He recalled that Chief McManus began his sales campaign practically from the moment the China Lake aircraft touched down on the Holloman runway:

> We started unloading our equipment, and we were met by an Air Force colonel, and he said, 'Glad to have you here at Holloman. Is there anything we can do to help you?' This chief said, 'Yeah, Colonel, we didn't bring any test equipment with us. We'd like to have you help us with the test equipment if you would.' With that, the colonel blanched and said, 'Gee, I don't think we've got any Sidewinder test equipment over here. What do you need?' And McManus, with a little smile, said, 'We just need a Simpson meter.'[69]

Few Air Force participants had paid much attention to Sidewinder's test preparations during the first Holloman visit, but now the word spread rapidly: Sidewinder was so simple that you needed only the most rudimentary test equipment. Actually, readying Sidewinder for flight was indisputably far simpler than the procedure its rival required, but even a missile designed for ease of use needed preflight testing that involved a bulky rate table, a huge air compressor, and a test console. The difficulty of lugging all that equipment along had again inspired Wilcox to decide, "All right. Make the missiles as good as you can make them, and we'll just take them. No flight test."

McManus never missed an opportunity to wage psychological warfare, and soon the weather gave him another chance to emphasize Sidewinder's ruggedness. As Amlie remembered,

> [T]he Hughes missiles were so delicate and fragile. They'd essentially wrap them in cotton every night, and they had a rainy spell down there, the wind blowing and the sand blowing, and the colonel said, 'Chief, should you take your missiles in?' We just left them on the airplane. And Mac said, 'No, it'd do them good.'[70]

Unlike the Holloman watchers on the ground, the Air Force pilots scheduled to fire the missiles were already predisposed in Sidewinder's favor. Evidence of the missile's ruggedness just increased their enthusiasm. After firing their Sidewinders, the pilots peered into the distance, trying to see the missiles and their tiny targets. Given the speeds, distances, and altitudes involved, the pilots had a difficult time judging what happened, but they were pretty sure that all six missiles had hit their targets or had been close enough to demonstrate guidance. The pilots were happy to report six consecutive direct hits.

The agreement had been that Holloman would collect the telemetry data and that China Lake would analyze it—a process that consumed several weeks. "Where adequate camera coverage permitted analysis of the firings, the missile appeared stable in flight and the aerodynamic capabilities checked with calculations," Wilcox reported to the Research Board. "Miss distance figures were greater than were reported by observers, however."[71] Ever the salesman, he presented the results as positively as he could, but what motivated his qualifying statement were data showing that every missile had in fact missed its target. The rollerons that had been taken off earlier would have solved the problem, but they had not as yet been reintroduced, since Sidewinder at low altitudes didn't appear to need the little gyro-stabilizing wheels.

To Cartwright fell the unpleasant duty of visiting Wright-Patterson Air Force Base to break the bad news to Colonel Paul Cool, the newly appointed Sidewinder project officer for the Air Research and Development Command. The colonel received Cartwright's confession with surprising equanimity. "Don't worry, it's too late now," he told the amazed China Laker in a calm voice. Cool explained that he had met a tight deadline to communicate the results of the high-altitude shoot-off by submitting his report based on the pilots' eyewitness accounts. Now he was determined not to muddy the waters with a second report contradicting the first. "If it hadn't been for that . . . delay between a requirement that the Air Force get a report and the telemetry getting turned out," Cartwright later speculated, "history might have been different."[72]

With the official report terming Project Red Hot a spectacular success, the Air Force jumped on the Sidewinder bandwagon with alacrity (not, however, abandoning Falcon, which in several versions, including a nuclear one, remained part of the Air Force arsenal until it was canceled in the Vietnam War era). Within days, Cool set up an expedited Sidewinder installation and test program, with the goal of using the missile on F-100C and F-86D aircraft. Later that year the Air Force sent an F-100A, an F-100C, and an F-104A to China Lake for use in test flights. The addition of these high-performance aircraft allowed visiting Air Force, Navy, and Marine Corps pilots to explore Sidewinder's capability in a demanding operational performance regime.

The high-altitude requirement imposed by Project Red Hot was symptomatic of a new emphasis among defense planners on weapons that would work at high altitudes. To compensate for the roll instability that had caused Sidewinder to miss at high altitudes, NOTS put redesigned rollerons on the missile's 1A version. Jagiello realized that Sidewinder's airframe needed more pitch-yaw damping, and he designed a canted hinge line for the rollerons that did the trick. The noise caused by the rollerons in their earlier installation disappeared. The little gyro wheels provided just the roll-rate damping that was needed.

After the Red Hot experience, the Air Force also wanted targets that simulated aircraft at high altitudes better than did the rockets China Lake had been using. Beginning with Navy-developed Pogo-Hi parachute targets rocket-launched from the ground, an Air Force evaluation program at Holloman under Captain Thomas U. "Tom" McElmurry's direction settled by 1958 on Hi-Fly targets, balloon-lofted aluminum delta-shaped platforms carrying flares. Subsequent tests showed promise that Sidewinder 1A could hit its target at altitudes of around 60,000 feet.[73]

The Air Force subsequently procured Sidewinder AIM-9B missiles for use on seven aircraft models in both the Tactical Air Command and the Air Defense Command.[74]

U.S. Navy photo LO 24721

F9F-8 aircraft firing Sidewinder to score a direct hit on the target drone's wingtip flare, February 1957.

Sidewinder Siblings—SARAH and IRAH

Although the Sidewinder team didn't admit it to the Air Force, two NOTS groups were already working on radar-homing versions that could potentially solve Sidewinder's lack of an all-weather capability. With Wilcox's appointment to head the Weapons Development Department (Code 40) in late 1955, McLean agreed to move Sidewinder into Code 40 too. That decision angered many on the Sidewinder team, notably Amlie, who believed the move occurred "because they [Code 40] were bankrupt and needed a program with a lot of money." In answer to his heated threat to quit rather than move to Code 40, others suggested that instead he "go upstairs and work with those radar nuts." He became head of AOD's Simulation and Analysis Branch, joining radar expert John Boyle and a small group in the north tower of Michelson Lab who were working on Raywinder, a radar-homing version of Sidewinder. In August 1957 Amlie and Boyle presented results of a successful Raywinder demonstration to Withington and other BuOrd and BuAer representatives, who gave the idea an enthusiastic reception.[75]

The Raywinder project never went beyond initial studies. But Amlie's branch was already pursuing the idea of putting a radar head on Sidewinder through another program, SARAH (Semiactive Radar Alternate Head), one of the two alternate seeker heads McLean had proposed in 1954. The other head, IRAH (Infrared Alternate Head), stayed with the main Sidewinder effort in Code 40. Each new head employed the same type of torque-balance control servo. IRAH had 60 seconds of guidance life; SARAH had 40. Each was intended to operate in aircraft flying at speeds of up to Mach 2.5 and with ceilings of up to 80,000 feet. The two missiles used the same fuze, warhead, rocket motor, wings, and launcher. Only the guidance-and-control groups were different. The idea behind the alternate heads was to make possible all-weather nose-on or tail-on attacks.

The IRAH version, designed to be fired nose-on against Mach 2 targets, had difficulty with being positioned properly for a nose-on attack. The pilot would fire the SARAH version in the tail attack in much the same way as he would fire an infrared missile except that he would have to illuminate the target with airborne intercept radar until SARAH reached its target. Because SARAH was designed to guide either passively (locking onto an emission coming from the target itself) or semiactively (guided by energy from an external source designating the target), a pilot who discovered that the target aircraft was jamming his radar, could still fire his missile, which would home on the target's radar jammer.[76]

The possibility of copyright infringement problems caused the IRAH and SARAH acronyms to be dropped on paper. IRAH became known officially as Mk 29 (IR), then as AIM-9D, while SARAH became Mk 30 (SAR), then AIM-9C.[77] NOTS folks, of course, continued to refer to the missiles by their original names.

Development of the AIM-9C began in 1957, with the missile entering the fleet in 1964. The AIM-9C was a semiactive, X-band, radar-guided version of Sidewinder, built as a complement to the AIM-9D Sidewinder infrared guided missile. The AIM-9C was designed to be used from F8D and F8E aircraft for head-on attacks against incoming bombers. Airborne intercept radars performed well under most conditions even though their inner workings depended on vacuum tubes rather than transistors. Because a semiactive-radar missile guides on signals transmitted by the launching aircraft and reflected by the target, the lack of Doppler processing made the missile's performance poor at low altitudes or in a lookdown situation, where the AIM-9C would confuse ground clutter for the legitimate signal. "Except for this limitation imposed by the radar of the launching aircraft, the performance of the AIM-9C was excellent," Amlie commented. He added that fleet pilots loved the missile. "But it turns out that the whole thing was a mistake because head-on shots don't occur in nature," he said. "Hardly ever. They're almost all tail shots, and the infrared missile's cheaper and more accurate."[78]

"One Big Job Done"

On 29 December 1955, the station shipped the last of numerous missiles, test equipment, and launchers to OPDEVFOR for the fleet evaluation scheduled to begin on 3 January 1956—only two days later than Wilcox had predicted in 1953. "Okay, one big job done, by God, done!" was the reaction of the jubilant Wilcox.[79] Sharing that enthusiasm, Ashworth wrote a congratulatory letter to all hands at NOTS expressing appreciation for the teamwork, technical skills, enthusiasm, and energy that made timely delivery possible.[80]

Because most problems had been fixed during the BuOrd development-evaluation phase, the missile had a remarkably smooth and rapid OPDEVFOR evaluation. The success of that process again proved the importance of having a military-civilian team on the spot to assess problems and incorporate necessary changes. Wherever Sidewinder appeared, there were NOTS engineers Frank Wentink and Robert R. "Bob" Sizemore, ready with instructions for assembling, handling, and using the weapon. Sidewinder's two-man field service unit first appeared on board *Randolph* in early summer 1956. The two China Lakers' hands-on help smoothed the way for Attack Squadron 46, flying F9F-8 aircraft, to introduce Sidewinder in the Sixth Fleet in July 1956. The following month, deployment of Sidewinder extended to the Western Pacific as Fighter Squadron 211 and its FJ-3 aircraft departed the U.S. West Coast on *Bon Homme Richard* (CVA-31) for Seventh Fleet operations. The two squadrons demonstrated in tests of about 200 missiles that they could destroy their targets more than 60 percent of the time.

In October 1956, after OPDEVFOR recommended that Sidewinder be released to the fleet, CNO Burke enthusiastically directed that both Navy and Marine Corps units be immediately and extensively refitted with Sidewinder. The Sidewinder 1A design release on 15 December 1956, incorporated a new internal gimbal system and a longer-burning gas generator grain that allowed increased guidance time. By early January four pilot-production units had been test fired, with three of them guiding properly.[81]

An amazingly low $3,000 cost per missile resulted from Sidewinder's basic design, which took into account producibility as well as tactical effectiveness. Most components were designed for simple, known manufacturing techniques. For example, the problem of how to attach thin-walled tubing to an end

U.S. Navy photo LHL 70825

Sidewinder as it entered the fleet in 1956.

Courtesy U.S. Naval Museum of Armament and Technology

Communication with a contractor to ensure producibility.
Sidewinder leaders Walt LaBerge (center) and Commander Wade Cone (right) confer with an unknown contractor.

closure plagued rocket designers for years. The Sidewinder solution, adapted from NOTS rockets, involved machining grooves in both the header and the tube, then placing both parts in a press with the proper dies, and forming the metal of the tube into the groove in the header.[82]

Sidewinder was the first guided missile purchased through competitive bidding. After NOTS invited bids from 25 companies for a pilot production run of 200 guidance-and-control sections, General Electric Company gained the first contract in April 1956. A few months later, the station invited both G.E. and Philco to submit bids for the production of 12,000 more units, to be delivered during the following fiscal year. These additional units would be procured from both sources, with the bidder offering the lower price receiving the larger proportion of the order. With a bid of around $2,600 per unit, G.E. undercut the Philco bid by about $200 per unit and received 60 percent of the order. That was a wake-up call for Philco, which improved its production procedures to the point that when the same bidding procedure was repeated for the following fiscal year, Philco could afford to bid $1,750 per unit, undercutting G.E. by $550 per unit and earning 70 percent of the contract.

That wasn't the last price cut, either; by the middle of 1959, the average contractor price for the guidance-and-control units was around $1,400, about half the initial bid. Part of that low cost could be attributed to the fact that most components were available through several supply sources. About 20 prime contractors supplied components, with those contractors in turn relying on more than 500 subcontractors.

As the day approached when the world's first fully operational air-to-air guided missile would be released to the fleet, Ashworth saw an excellent opportunity to publicize both Sidewinder and the creative place that had developed it. He hired Los Angeles public-relations specialist Ernest N. "Ernie" George in September 1956 to make sure the Sidewinder story reached the world's press. On 16 October, the DoD Office of Public Information released the news that "the Navy's new air-to-air guided missile, the SIDEWINDER, is now operational and is on board fleet units at sea." George had his press kits ready, and within days photographs and articles about Sidewinder, McLean, and China Lake appeared in newspapers and magazines across the nation. Radio and television networks carried the story, with some Los Angeles TV stations showing the NOTS films repeatedly.

George followed up with media events featuring a pressure-suit-clad Tierney, sporting a wide grin and delivering the widely quoted opinion that "A pilot with a Sidewinder is like a fighter going into the ring with a six-foot reach over the other guy." So popular did Tierney become as a Sidewinder figurehead that the Technical Information Department designed a card resembling a baseball trading card, on its face Tierney standing proudly beside a Sidewinder, and on its back information about NOTS and its new

SIDEWINDER and Navy Pilot
(Official U. S. Navy Photo)

The strange pair on this card do not represent a space traveler of the 25th century and a missile of the future, but rather one of today's Navy pilots in a high-altitude suit and the Navy's new guided missile, the SIDEWINDER.

. . . .

THE NOTS SIDEWINDER

The Navy's SIDEWINDER air-to-air guided missile is appropriately named after the fast-striking and deadly desert rattlesnake, the sidewinder. SIDEWINDER can destroy high-speed enemy bombers from sea level to above 50,000 feet. Highly reliable, it is designed for simplicity in production and use, and for low cost in production.

SIDEWINDER was developed by the U. S. Naval Ordnance Test Station (NOTS), China Lake, Calif. NOTS, the Navy's largest ordnance research and development center, is a Bureau of Ordnance facility.

NOTS engineers and scientists at China Lake and Pasadena, Calif., carry weapon developments through from idea to finished weapons ready for mass production and fleet use.

. . . .

For information on employment opportunities at NOTS write:

U. S. NAVAL ORDNANCE TEST STATION
Head, Employment Division (Code 652)
China Lake, California

China Lake archives

Front and back of Sidewinder trading card.

Glenn Tierney is shown in 1956 with a dummy missile.

missile. "They sent those all over the country," Tierney said later. "My mother carried one in her wallet."[83]

Also widely quoted was Ashworth, who told the press that the new missile was "probably the most effective air-to-air missile now operational anywhere in the world." He and McLean stressed Sidewinder's simplicity. "This new missile has very few moving parts and no more electronic components than an ordinary radio," they told the press, adding that missile assembly and use could be accomplished with little or no specialized technical training.[84]

Hundreds of employees in every department at China Lake had worked directly on Sidewinder; hundreds more had contributed technology developed for other programs. LaBerge encapsulated the general feeling with the tongue-in-cheek comment that "I feel honored to be one of the over four thousand people I have met who single-handedly invented Sidewinder."[85] In November 1957, Commander Wade Cone, Sidewinder project coordinator for the AOD Air to Air Weapons Division, unveiled a symbol of those contributions—a 10-by-16-foot mural on the east wall of Michelson Laboratory machine shop. "We Built Sidewinder," the mural proclaimed, punctuating that claim with a depiction of Sidewinder streaking in front of a massive fist.

Down the hall by the Ballistics Division door, a sign appeared, "We had nothing to do with Sidewinder." The sign was meant mostly in jest, since the

U.S. Navy photo LHL 258645

Sidewinder mural on the wall of Michelson Laboratory machine shop.

ROCKETEER

Vol. XII, 42 — U.S. Naval Ordnance Test Station, China Lake, Calif. — October 19, 1956

To The Sea -- 'A SIDEWINDER'

Deadly Desert Rattler In Form of Guided Missile

The Department of the Navy announced this week that the Navy's new air-to-air guided missile, SIDEWINDER, is now operational and is on board fleet units at sea. This missile is named after the fast striking, deadly, desert rattlesnake—the sidewinder. The SIDEWINDER missile was conceived here at NOTS and is now in production by the Philco Corporation of Philadelphia, Pennsylvania.

The highly successful working relationship between a Government agency possessing combat experienced research and development personnel, and a large private industrial concern possessing high level production and engineering personnel, which led to the fleet operational SIDEWINDER, is almost unique in today's missile business. The requirement for SIDEWINDER as assigned to the Naval Ordnance Test Station in 1950 and the original concept of SIDEWINDER was evolved by Dr. Wm. B. McLean, now Technical Director of NOTS and the Station's civilian scientists and engineers working with naval officers familiar with fleet requirements, converted the original concept of SIDEWINDER into the weapon that it is today.

this missile without undergoing any specialized technical training. Navy and Marine pilots will require little or no special flight training to effectively use SIDEWINDER against enemy aircraft in the defense of our fleets at sea.

Other industrial concerns connected with the SIDEWINDER program are the Avion Division of the American Car and Foundry Industries at Paramus, New Jersey who produced experimental missiles used in the research and development program and the General Electric Company of Utica, New York who has recently been awarded a production contract. The Eastman Kodak Company of Rochester, New York and the Bulova Research and Develop-

Courtesy U.S. Naval Museum of Armament and Technology

McLean on triumphant *Rocketeer* front page, 19 October 1956.

division had done valuable work on Sidewinder ballistics, but it may have also reflected the concern of the ballisticians that their jobs were changing.[86] However, most employees adapted well in an era where there was plenty of work available in Sidewinder, in conventional weapons (soon making a transition to the famous "Eye" series of free-fall weapons in the 1960s and 1970s), and in numerous other programs. Former rocketeer Ted Lotee flowed with the times by leaving his job as head of Code 40's Ordnance Components Division in 1957 to spend the next 20 years heading the In-Service Weapons Support Division in the Engineering Department. Far from resenting Sidewinder's success, he commented, "It was always a pleasure to do business with those people because they were gung ho and really wanted the program to succeed and really had their backs and hearts into it."[87]

16

Pilots, Targets, Tactics

Airspace and range assets, always a crucial part of China Lake's value to national defense, improved significantly during the 1950s. The establishment of a military restricted airspace overlying some 15,000 square miles of Southern California and extending from the ground to infinity immeasurably enhanced the instrumented aerial ranges. As the demand increased for realistic missile tests, the station responded by acquiring its own drone unit, developing simple but effective targets, and serving as host to a series of test and training units, notably including Air Development Squadron Five.

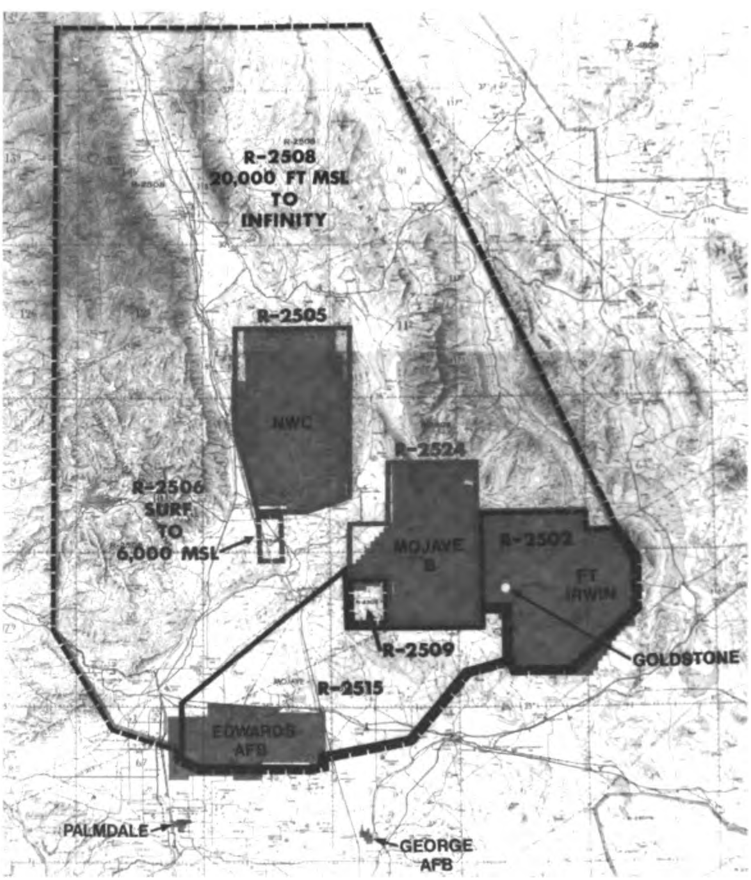
Airspace and Range Improvements

Station founders had envisioned the China Lake ranges and military airspace as large enough to encompass all the tests NOTS rocketeers could dream up. But with the longer-range guided missiles of the 1950s, test personnel experienced increasing difficulty in conducting safe operations within the airspace available. Flight operations were complicated by the possibility that small aircraft would venture over test areas. Airspace danger areas kept civil aircraft from flying directly over the most heavily used areas, but as flight traffic increased, larger restricted airspace was needed to ensure test safety. In 1949 the station had complained to the Civil Aeronautics Authority (CAA) that NOTS test activities were hazardous to civilian aircraft flying near the station's danger areas.[1] A vocal group of commercial and private pilots had raised objections to further restriction of the desert skies, however, and the seven danger areas set up in the station's early days remained unchanged.

The possibility of new commercial encroachments arose in 1953, when three small airlines proposed flying over parts of NOTS several times a day on routes between Bakersfield and Las Vegas. Edwards Air Force Base then asked the station to support an objection to an existing Bakersfield-to-Daggett airway that crossed the Edwards base and NOTS' Mojave B Range. This narrow corridor for commercial air traffic had become increasingly congested, particularly when bad weather diverted southbound San Francisco aircraft. Tom

Connolly, the station's experimental officer, presented the problem to the Los Angeles Regional Air Space Subcommittee of the CAA, but discussions soon bogged down.[2] The issue was still not resolved when Connolly left the station in June 1954, although by then a joint Air Force and Navy proposal had been drafted that would set aside restricted military airspace of some 15,000 square miles and that would spell out new danger areas where private aircraft would not be allowed.

Hardy, the assistant experimental officer, met in December 1954 with 28 local pilots at a small airfield in Ridgecrest. The CAA subcommittee still had not acted on the Air Force-Navy proposal. The pilots had heard rumors that all nonmilitary flying would soon be prohibited over much of the Mojave Desert. Hardy explained that the military services had no intention of preventing commercial and private flying in the Mojave Desert, but that for safety's sake all space from the ground up in certain danger zones had to be off limits to private aircraft. He described the proposed restricted area, bounded approximately by



U.S. Navy photo LHL 182391, courtesy John Di Pol

Restricted airspace R-2508 superimposed on part of Southern California and Nevada.

The land areas of the military installations of the Northern Mojave Desert are shown as gray shapes. The configuration, shown in 1974, remained substantially the same as that established in 1955.

Palmdale on the south, Big Pine on the north, Wheeler Ridge on the west, and the California-Nevada line on the east.[3]

In January 1955 Tom Walker, the new experimental officer, came home from a meeting of the CAA subcommittee with good news: the authority had approved the proposed 15,000-square-mile restricted area, as well as a new airspace danger area over Saline Valley to the north of the China Lake complex.[4] A danger area near Edwards Air Force Base was also enlarged. Only military aircraft would fly in seven danger areas. Outside the danger areas, but within the restricted area, private aircraft would be permitted up to a ceiling of 20,000 feet above sea level. These new regulations offered a compromise to nonmilitary users in that they opened Owens Valley and Death Valley to private flying. The station was designated as the controlling agency for the restricted area, with control of specific danger areas delegated to the individual commands.[5]

With an open exchange of information, the initial hostility of local pilots melted away. "This case demonstrates the excellent cooperation between the civil and military agencies of government and civilian aviation groups in solving a complex problem for the general welfare of all concerned," commented the CAA subcommittee.[6]

The year 1955 was also significant for China Lake's ground ranges. With completion of permanent facilities at G-1 Range, the move back from temporary G-1, about a mile north of permanent G-1, was completed that February, with the move to permanent G-2 completed that August. The final process of moving took many months to accomplish because testing continued even as the move took place. Helping the Test Department fulfill special requirements were the Engineering Department, which fabricated many essential items; BuOrd contractors, who came up with two new guidance radars; and the Naval Gun Factory, which sent a special crew to wire the range fire-control system.[7]

Drones and Other Moving Targets

One of the most difficult aspects of test preparations involved arranging for moving targets. As Sidewinder developed to where it needed air testing and as the station began coordinating Terrier's BuOrd evaluation program in the mid-1950s, high-speed aerial targets were in short supply. Whenever NOTS test personnel were lucky enough to get their hands on a drone, they hesitated to use it for fear of shooting down a valuable asset.

The Naval Air Missile Test Center at Point Mugu, the BuAer activity responsible for developmental testing of pilotless aircraft since 1946, owned most of the Navy's West Coast drone resources. Whenever a test over China

Lake ranges required a remotely controlled maneuverable target, the station had to ask NAMTC for a drone. Point Mugu officials subjected their drones reluctantly to the ever-more-accurate weaponry of China Lake. NAMTC agreed to provide drone services for a day a week, but even that schedule, inadequate enough from a China Lake perspective, was sometimes disrupted when weather conditions at Point Mugu forced cancellations.

Then in 1954 the Terrier program changed the situation. Just as Terrier's high-priority schedule and abundant funding led to modernization of China Lake's ranges, the missile's test program was also instrumental in the establishment of a drone unit at NAF. The unit began with 10 F6F-5K Hellcats, venerable aircraft of the World War II era converted to radio-controlled guided missiles during the Korean conflict. Four F8F Bearcats and one F2F Banshee were fitted out as control planes. The unit successfully launched its first pilotless aircraft in August 1954. AOD took delivery in March 1955 of several new K-D drones, miniature aircraft with wingspans of less than 12 feet.

Each drone, painted bright red to aid in identification, was controlled from the ground by an instrumented cart known as a foxcart. When the drone was safely airborne, a control plane, painted a distinctive blue and yellow, took over, with the pilot maintaining visual and radio control until control could be transferred over G Range to another cart, "Fox Jr.," which used radar to maneuver the drone far beyond visual range.[8] With these procedures, drone flights were normally tightly controlled. But the remoteness of China Lake ranges proved its value in several instances of lost radio control.

An uncontrolled drone would normally circle until it ran out of gas, then crash on isolated NOTS land. But occasionally an errant drone would stray over more populated areas. According to NOTS lore, one vagrant ran out of

Photo by Robert D. Schmidt

F6F-5K Hellcat drones and AD Skyraider at Armitage Field, 1954.

gas in the State of Washington and landed intact. James E. "Jim" Crawforth, who was visiting relatives in the area, said he had to answer to a swarm of authorities when he owned up to working for the place identified on the drone as "U.S. Navy China Lake."[9] Even as this and a few drone excursions over Southern California entered the China Lake repertoire, employees of the Test Department's Instrument Development Division, notably Floyd A. Kinder and Leroy D. Marquardt, were solving the problem through improvements in drone reliability and controllability.[10]

These new resources helped the station's aerial test programs, but weren't the whole answer since target drones normally had only about four or five flights before they were destroyed. Adding wingtip flares helped drone survivability, but test conductors still used the drones only when no other alternative would work. Most of the time, the station used rocket flares or target simulators. A team at China Lake led by NAF chief project pilot Lieutenant Commander R. R. "Van" Vancil and Leonard W. Seeley, head of the AOD Flight Evaluation Branch, came up with another innovative solution: a plywood target in the shape of a dart that an aircraft could tow through the air at high speeds.[11]

Representatives of other defense installations expressed amazement at the revolutionary improvement the Dart Tow Target represented. Towed targets had been used for decades, but the problem had been in how to get the targets aloft without damaging them. Various methods had been tried, including mounting the target on a sled with the host aircraft unreeling the tow line from the air. These practices were successful with banners and other light targets, but not with larger and heavier targets.

The NAF and AOD team solved the problem by refining a method used for gliders. A plywood target 12 feet long and four feet wide at the stern was attached at its center of gravity to a long nylon line, then a loop from the line was strung between two 10-foot-high poles. The towing aircraft snagged the line with a tailhook, then began a 30-degree climb, an angle calculated to abet the drag force of the airstream and cause a long drooping arc in the towing line. When the entire line was airborne, the target gently floated off the ground. The line's arc kept the target out of alignment with the towing aircraft so that attacking pilots could fire from various angles, including behind the target, without endangering the towing aircraft. With completion of target practice, the towing aircraft released the line and let Dart and its leash fall to the ground. The line could be reused several times, as could Dart itself. Most impressively, Dart could be towed at speeds in excess of 400 knots, more than twice as fast as the speeds allowed by other towed targets.[12]

Photo by George Silberberg, courtesy S. Joel Premselaar

F4D-1 Skyray, piloted by Lieutenant Commander Joel Premselaar, hooking the line of a Dart Tow Target.

To keep the target as inexpensive as possible, the ever-practical Newt Ward came up with a cost-effective way to procure materials through the supply system. When he faced roadblocks set up by supply regulations, he simply wrote a requisition for sheets of plywood, then had AOD employees assemble the inexpensive cruciform targets.[13]

In late 1954 NOTS demonstrated its target at China Lake and at Eglin Air Force Base, Florida, to pilots of F-94C and F-86D aircraft from Hamilton and George Air Force Bases.[14] Dart was initially configured to carry 16 T-131 flares, but after the ejecta and the smoke from the flares caused early functioning of the Sidewinder proximity fuze, improved flares were devised.[15]

The Dart target, which later saw service with both the Navy and the Air Force, well illustrates the NOTS approach to a technical problem: seek a simple, practical solution, then rely on in-house resources and take the most pragmatic route to make the solution a reality.

Guided Missile Units

China Lake's increasing role in missile development and testing not only changed the character of the work and the capabilities of the ranges, but also resulted in the arrival of new tenant commands at a pace the station infrastructure could scarcely absorb. Marine Corps, Navy, even Army units came to NOTS to receive training and to help with a myriad of tasks to get missiles ready for operational use.[16]

Naval Guided Missile Training Unit No. 21, a small group of a dozen men, arrived from Applied Physics Laboratory in March 1950 for training in Terrier operations. The unit, which grew slightly over the next few months, was soon reassigned to sea duty and replaced by Naval Guided Missile Training Unit No. 22, which in turn served a few months before going to sea. Both mobile units were established to assist in Terrier development and testing, then to provide the fleet with trained personnel familiar with the missile's operation, maintenance, and repair.

After the concept worked well with the two smaller units, the Bureau of Ordnance sent a larger unit, Guided Missile Unit (GMU) 61, to China Lake on 16 July 1953. The unit, under Commander Albert S. "Al" Yesensky, was assigned a daunting mission: to assist in the development, testing, and repair of Sidewinder, OMAR, and Terrier and all associated equipment.[17]

Tierney, who succeeded Yesensky as the unit's commanding officer in September 1954, recalled that he soon recognized the difficulty of accomplishing all the tasks the group was assigned. He suggested to his superiors in Washington that since Sidewinder was destined to take priority at China Lake, GMU-61 should focus on Sidewinder, with another unit set up to support Terrier.[18] On 24 June 1955, the Terrier section of GMU-61 was redesignated GMU-25 by the Secretary of the Navy. Both GMU-25 and GMU-61 were under the military control of the Eleventh Naval District and the management control of BuOrd. Tierney's original force of 10 officers and 73 men was pared down to three officers and 24 men. He and his unit turned to their more manageable task with gusto.

The mission of GMU-61 was subsequently enlarged to encompass flight test of the Sidewinder during developmental testing and BuOrd evaluation, as well as technical assistance during the fleet evaluation of the missile. The pilots of GMU-61 flew hundreds of developmental and evaluation flights, and the ground personnel handled hundreds of missiles without a single accident. In addition, the unit worked on test launchers and other equipment in Michelson Laboratory or wherever they were needed and accomplished numerous flights to proof equipment that would be subjected to the strain of combat operations. "Glenn Tierney was a tower of strength," said Tom Amlie. "He always had a smile on his handsome face, and he and his men never let us down, not once."[19]

Courtesy Michael Kott

Guided Missile Unit 61 patch.

Commander Selden N. May, the last commanding officer of Guided Missile Unit 61, cutting the cake at a disestablishment ceremony, July 1969.
The entire unit surrounds May. The cake reads "GMU-61 1952-1959 Long Live Sidewinder."

The officers and men of GMU-25 under the command of Lieutenant (j.g.) Joel Waldman picked up the Terrier part of GMU-61's former tasks, with a mission to assemble, operate, maintain, and repair Convair's production model of Terrier. The trained missilemen, electronics technicians, and gunners' mates of the unit worked on the fire-control radar equipment and associated computers and directors tracking the target drone and relaying that information to the missile, as well as handling the missile, assembling it for launching, and triggering it out of its launcher. The unit also made its training and experience available to the crews of the original U.S. guided-missile ships, *Norton Sound*, *Boston*, *Canberra*, and *Gyatt* (DDG-712).[20]

The Marine Corps, a significant presence at NOTS from the beginning, was widely identified at China Lake with snappy salutes at the main gate and security duties throughout the station. Marine training units assigned to NOTS in the 1950s also supported weapon tests and evaluations, and learned how to handle the weapons to which they were assigned. The First Provisional Marine Guided Missile Battalion, which arrived in 1950, was joined in 1951 by a 25-man Artillery Test Unit from Camp Pendleton, a unit assigned to tests at Randsburg Wash. Those two units swelled the Marine presence at NOTS to about 250 men.[21]

The increased emphasis on Terrier tests, as well as commitments to test and maintain several Army and Marine Corps fire-control systems, meant an overwhelming workload for the Marine provisional battalion. But help was on the way. During a series of Terrier guided-missile conferences held at Marine

Corps headquarters in February 1954, the Navy and the Marines agreed to activate a new organization, First Terrier Surface-to-Air Missile (SAM) Battalion, by January 1955. The plan was to increase the size of the battalion to the full strength of 30 officers and 447 enlisted men as soon as possible after initial activation. As the battalion gained strength and experience at NOTS, permanent facilities would be built at the Marine Corps Training Center at Twentynine Palms, a desert community about 220 miles southeast of China Lake. Until then, part of the battalion would be stationed at China Lake and part at Twentynine Palms.

In May 1954 Marine Lieutenant Colonel J. O. Blackwell, commanding officer of the provisional battalion, told the Commandant of the Marine Corps that dividing a limited number of technical people between the two locations meant that "operations will suffer in both cases." He requested that his headquarters, a service battery, and two firing batteries be added to the resources already at NOTS, with the First Provisional Guided Missile Battalion to be simultaneously deactivated. As soon as each firing battery was trained at NOTS, he said, that battery would be moved to Twentynine Palms.[22] The Research Board worried about the tight housing situation at NOTS, but nevertheless agreed to endorse the proposal "with a realistic statement of the limitations in available housing and identification of other factors pertinent to the services that would be provided by NOTS."[23]

Blackwell's plan became a reality on 7 February 1955, when the First Provisional Marine Guided Missile Battalion officially became the First Terrier SAM Battalion, established at NOTS under his command. Because the battalion's visit to China Lake was planned to last 16 months or less, no existing facilities were altered. Blackwell and his men began work immediately, assisting NOTS and contractor personnel with a combined BuOrd and Marine Corps technical evaluation of Terrier.[24] Within the following year, 60 of the 125 Terriers fired during the missile's evaluation program flew over NOTS, with *Norton Sound* the platform for the other 65 tests. Fred M. Ashbrook and other representatives from the Test Department, as well as from the Weapons Planning Group, assisted with the evaluation.[25]

In October 1955, in a move consistent with Blackwell's plan, the Marine Commandant notified NOTS that the battalion would move in phases to Twentynine Palms, with the entire move to be completed before 30 June 1956. Since Terrier testing at NOTS was still going strong, he proposed replacing the battalion with a smaller Marine Corps Guided Missile Test Unit of six officers and about 50 men. Most of the unit would consist of men reassigned from

First Terrier SAM.[26] The new unit was established as a tenant of NOTS under the administrative control of the commanding officer of the NOTS Marine Barracks, with the main battalion leaving China Lake in early May.[27]

Arrival of a Squadron

The departure of First Terrier SAM Battalion cleared the way for Air Development Squadron (VX) 5 to begin a long-anticipated move to China Lake. In a later incarnation as VX-9, the squadron is still flying the desert skies to test the Navy's aerial tactics and weapons.[28] But the decision process that brought VX-5 to China Lake in 1956 was far from easy.

The squadron got its start at Naval Air Station, Moffett Field, California, on 18 June 1951, with 15 officers, 100 enlisted personnel, and nine AD Skyraider aircraft. Tom Walker, the first commanding officer of the "Vampires," answered operationally to Commander Operational Development Force, and administratively to Commander Fleet Air Alameda. The squadron's aircraft inventory expanded rapidly to support the mission for which the group had been established: developing tactics for nuclear bombs to be delivered from carrier-based aircraft. That mission brought the squadron regularly to China Lake where maneuvers could be practiced without fear of encroachment.[29] By June 1952, when Walker sent NOTS a memo spelling out his space and material requirements, the squadron had 23 officers and 122 enlisted personnel and expected to soon more than double in size. In VX-5's stable were six different types of aircraft, 14 aircraft in all, with 16 more expected within a few months.

Commander Naval Air Force Pacific Fleet was eager to move VX-5 along to NOTS not just because the squadron was already working closely with China Lake but also because the space vacated at Moffett Field could then be occupied by an all-jet air group. Fred Brown, who was still NOTS technical director when negotiations began to bring VX-5 to NOTS, traveled to Washington to urge Parsons to oppose the move. Brown worried about the effect the squadron would have on the station's predominantly civilian scientific and engineering philosophy. "Operational military personnel operate in a basically different atmosphere and with a basically different philosophy of how to do things," he told Parsons. "We must have a mechanism for obtaining the operational point of view on what we do but not on how we do it." Parsons' reported response was to point diplomatically to a statement by J. Robert Oppenheimer that "the best way to insure predominance of the scientific-engineering philosophy was to have a 'robust' organization."[30] Although other station leaders don't appear

Air Development Squadron 5 pilots beside an F2H-3 Banshee, 1954.

Lieutenant Newton L. Wheat is third from left. Fourth from left is Lieutenant S. Joel Premselaar, and crouched in front is Commander Harold H. Eppes, Jr., VX-5 commanding officer. The squadron was then based at Moffett Field.

to have shared Brown's philosophical fears, they did worry about logistics needs—particularly for housing—that the squadron would bring.

Walker also had reservations about the move. He recognized the advantages of the China Lake location that included the "opportunity to continually operate in close proximity to target areas," as well as excellent weather and closer teamwork with NOTS personnel, but worried about the effect on squadron morale of "a move to a location where dependent housing is critical" and about the possible "loss of the 'fleet point of view'" that might result from operating at a shore activity where no other fleet units were based. He concluded, however, that the advantages outweighed the disadvantages and that "from purely a squadron point of view such a move as is proposed would benefit both the squadron and the Operational Development Force."[31]

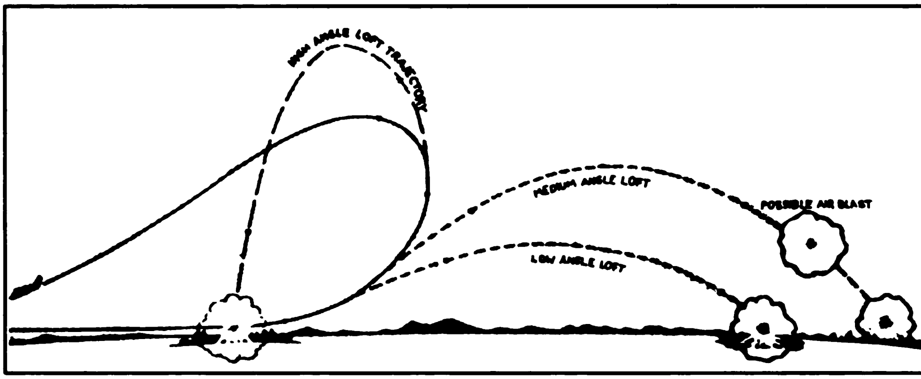
As Connolly subsequently commented in a draft memo for the NOTS commander's signature, the squadron was already using NOTS ranges for a week or two at a time, but these visits were expensive. "These circumstances suggested rather strongly that basing VX-5 permanently at NOTS might be a logical plan, offering the prospect of even closer liaison with the NOTS technical staff, continued use of the gunnery ranges in a more stable and consistent fashion, and utilization of the excellent flying facilities and weather which prevail," Connolly said. He expressed the opinion that the ranges and T&E support structure could meet the additional demands VX-5's arrival would impose. "It is the inability of NOTS to house married officers and enlisted men and their families on the base, and the current complete lack of available private dwellings for rent or purchase in the environs, that poses the greatest problem," he said.

The letter, which Vieweg subsequently signed and sent, went on to emphasize the station's willingness, indeed eagerness, to host a fleet unit that could help close "the wide gap that separates those engaged in weapon design and development and those who must use the weapons in combat," but only if BuOrd supported station efforts to ease its tough housing situation and to accommodate the squadron's other logistical needs.[32] Support was forthcoming, but the necessary funding and planning for construction took time.

In November 1954 Walker reported to the Research Board that BuOrd had agreed to build hangars and other facilities to accommodate VX-5, which would probably not arrive at China Lake for at least a year.[33] Hangar deficiencies at NOTS were also a source of frustration for the pilots already stationed at NAF. "I cannot reconcile the inadequate shop facilities and talent in use at hangar #2," Vancil wrote Newt Ward. "Your great white tower at the lab with its impressive facilities and smattering of talent and brains, seems to funnel its ideas (when investigations applicable to aircraft are concerned) to a shoe string outfit that is improperly equipped to make hardware out of your ideas."[34]

In May 1955 CNO Admiral Robert B. Carney agreed three months before his retirement to defer the date of VX-5's transfer to China Lake pending action to secure adequate facilities. BuOrd Chief Withington agreed to support with high priority the necessary hangar, storage, and working spaces.[35] Even with support from the top, however, construction of a new hangar wouldn't begin until January 1958. Unwilling to wait longer, CNO Arleigh Burke ordered VX-5 to China Lake. The squadron's commanding officer, Captain Fillmore B. Gilkeson, and an advance detachment arrived at NOTS on 18 April 1956, with the entire squadron of 30 officers and 200 men squeezing into NAF's available facilities by the following July.[36]

With its new more convenient, albeit much more crowded, location established, the squadron continued its pioneering work on techniques of over-the-shoulder, high-altitude, dive, toss, glide, loft, skip, radar, and low-level bombing. In particular, the squadron developed a reputation as a pioneer in the



Rocketeer, 22 November 1957

Graphic depiction of VX-5-developed loft bombing technique.

field for its loft and over-the-shoulder bombing techniques, both designed to allow accurate delivery of a special weapon and buy the pilot the necessary time to get his aircraft out of harm's way. VX-5 pilots developed those techniques primarily over Charlie Range, where a superb civilian crew under the cheerful, efficient leadership of Duane Mack provided much-appreciated ground support. In a preview of the massive combined efforts that today involve China Lake, Edwards, and Point Mugu in coordinated live tests and simulations, carriers up and down the Pacific Coast routinely practiced fleet strikes with Charlie Range designated as an enemy target.

The caliber of the support provided by Mack and his technicians resulted in frequent commendations, the most succinct coming from the commanding officer of Attack Squadron 153 out of Miramar, who sent Mack a photograph of the squadron autographed by the words, "Personnel of Charlie Range; the most cooperative and best run target in the Navy."[37]

Expansion of Work at Armitage Field

Even as VX-5 arrived and squeezed into facilities at Armitage Field, the work of the pilots and support personnel at NAF continued to expand. The NAF organization, which in 1948 had the mission of supporting "research, development, testing and evaluation studies of aviation ordnance equipment and munitions, including aircraft fire control systems, aircraft rockets and rocket launchers," had added test support for guided missiles and underwater ordnance, as well as target drone operations to its responsibilities in 1954, with aircraft weapons added to the lengthening list in 1955.

A more generic mission adopted in 1956 made sure NAF would be there for whatever aircraft support tasks NOTS needed: "Maintain and operate facilities

Naval Air Facility, October 1959.
To the west are Owens Peak and other peaks of the southern Sierra Nevada.

and provide services and material to support research, development, test and evaluation operations of the U.S. Naval Ordnance Test Station, China Lake, California, and other activities and units as designated by the Chief of Naval Operations."[38] A welcome constant in those changes was the NAF Operations Department's test scheduler and coordinator, James L. "Jim" Heflin, described in an AOD skit as "that old telephoning schedule-making, fly-casting artist" and commended by visiting squadrons for his ability to coordinate the many-layered land and airspace demands of tests whose needs frequently conflicted with those of other tests.[39] Another vital asset was John E. Kleine, who ultimately became the central scheduler for all Test Department ranges. He and Heflin had a close, harmonious working relationship essential for coordinating the array of resources needed to carry out complex testing requirements.[40]

The tremendous growth in capability and diversity of China Lake's range and airfield assets of the 1950s came through BuOrd's active support, earned by a cohesive military-civilian team functioning in step with the demands of the station's programs. The buildup of the ranges and airspace during this era was part of a continuous improvement process still going on today, with evolving technology and highly trained people at China Lake functioning as part of a massive West Coast test and evaluation complex. Similarly, the increasing diversity of range customers NOTS experienced in the 1950s signaled even broader demands today, when the cloudless skies and superb facilities in the Indian Wells Valley attract an international clientele.

17

Response to Sputnik

When the Soviet Union sent the world's first man-made satellite into orbit on 4 October 1957, U.S. scientists responded with a host of satellite proposals designed to establish American supremacy in space. One of these endeavors was the NOTS Project, or NOTSNIK, a hasty effort to loft a small satellite into orbit from a tactical aircraft. China Lakers plunged into this work with their trademark enthusiasm. The station was also influenced by another outcome of the Sputnik success: an increased emphasis on science and technology that led to major changes in the structure of the Department of Defense.

Challenges for a New Commander

As Hack Wilson observed, Dick Ashworth was "a pretty hard act to follow." After two years as NOTS commander, Ashworth reported to Jacksonville, Florida, as commanding officer of the carrier *Franklin D. Roosevelt* (CVA-42). On 6 September 1957, he turned over station command to Captain William W. "Bill" Hollister. Ashworth's effectiveness at NOTS had been strengthened by the widespread recognition that he was destined for higher assignments. Hollister, however, had to run the station without the advantages of a rising star. He had punched all the right tickets on his way to NOTS, but he apparently realized that service at China Lake was destined to be his "retirement pull."[1]


U.S. Navy photo

Captain William W. Hollister.

Hollister was a Naval Academy graduate and an experienced aviator, having flown seaplanes, carrier fighters, and bombers during his career. His technical training included a master's degree in aeronautical engineering from Caltech. During World War II he was a bomber pilot over the icy North Atlantic, where blizzards and high winds added an extra element of danger to already hazardous antisubmarine and convoy escort assignments. His next assignment brought him to Washington as head of the BuAer Torpedo-Bomber Design Branch.

After the war he served in Asiatic waters as executive officer of both *Belleau Wood* (CVL-24) and *Boxer* (CV-21), then reported to the Naval Postgraduate School, where he was in charge of the aeronautical engineering curriculum. In subsequent assignments he became commanding officer of Air Transport Squadron Three at Moffett Field; Director of Aviation Armament Test at the Naval Air Test Center, Patuxent River; and commanding officer of the seaplane tender *Kenneth Whiting* (AV-14). He served on the staff of Commander Naval Air Force Pacific Fleet, and during the year before he reported to NOTS was commanding officer of *Hornet* (CVA-12).[2]

The station's new commander soon learned that his retirement pull would offer challenges as daunting as any of his career. Even as the Hollister family moved into 1 Enterprise Road, Bill McLean's mavericks were planning to enter a new area, one not just outside the NOTS mission, but also outside the atmosphere of Earth itself.

Red Moon Rising

In 1956 Howie Wilcox and others, spurred on by McLean, began looking into the feasibility of spin-stabilized suborbital rockets to obtain surveillance pictures of the ocean's surface. Wilcox envisioned these rockets as being too low and slow to orbit, but high and fast enough to move out over long ranges, scanning the ocean ahead of naval task forces. He dreamed, too, of more ambitious projects employing rocket technology to bring the Navy into space exploration.[3]

Others were working toward that same dream. Ever since Wernher von Braun predicted in May 1945 that peacetime applications of V-2 rocket technology could result in earth satellites, manned space stations, and flights to the moon and beyond, American scientists had pondered the prospect of sending rockets into orbit. The Soviet Union was pursuing a program to launch a satellite, but limited funding, cognizance issues accompanying establishment of the Department of Defense, and high-priority work on intercontinental ballistic missiles kept U.S. satellite programs from developing at a comparable pace.

In 1955 President Eisenhower decided that the U.S. contribution to the International Geophysical Year would be Project Vanguard, a National Science Foundation program that assigned the Navy responsibility for developing the launch vehicle. Vanguard, a small, instrumented ball weighing less than 22 pounds, would be lofted into orbit by a three-stage rocket employing Viking as the first stage, an improved Aerobee ("Aerobee-Hi") rocket as the second stage, and a spin-stabilized solid-propellant rocket as the third stage. These relatively inexpensive off-the-shelf components represented the administration's frugal approach to scientific endeavor, as well as the President's determination to minimize military participation in space exploration.[4] In January 1956 the NOTS *Rocketeer* was among the newspapers across the nation running a joint Navy and Air Force announcement that Project Vanguard would launch the first man-made earth satellite into outer space from Patrick Air Force Base in Florida in 1957 or 1958.[5] Exciting as this news was to the American public, those more aware of the state of the art knew that the U.S. program was already far behind its USSR rival and that the limited Vanguard effort was not likely to catch up. The Navy was told to keep its launch vehicle small and to avoid interfering with military rocket programs. "These two requirements together almost foredoomed it to failure," Dr. Herbert F. York later commented.[6]

In August 1957 Soviet Premier Nikita Khrushchev announced the launch of a long-distance multistage intercontinental ballistic missile whose trajectory took it the length of Siberia and whose success demonstrated, according to Khrushchev, that the Soviet Union could now "direct missiles into any part of the world." U.S. rocket experts predicted that America was "facing a technological Pearl Harbor."[7] These predictions did not lead to new funding, however, since Washington decision-makers were more interested in cutting costs to justify a 1958 tax cut. Secretary of Defense Wilson slowed the pace for all types of military projects, conspicuously including the ballistic missiles necessary to loft satellites into orbit. As the so-called missile gap developed between Soviet and U.S. space programs, many American policymakers ignored intelligence reports on Soviet activities, preferring to believe in what journalists Joseph and Stewart Alsop termed "their own public soothing syrup."[8]

Despite the official decision that Vanguard would launch the first American satellite, von Braun and his team were working hard in Huntsville, Alabama, to develop the Army's Jupiter C (a Redstone missile with clusters of small rockets for the upper stages). On 7 August 1957, a Jupiter C carried a scale-model nose cone 1,200 miles and to an altitude of 600 miles from Cape Canaveral. But no U.S. satellite was yet ready to achieve orbit.[9]

Mock-up of Sputnik I.

On Friday, 4 October 1957, the Soviet Union launched the world's first man-made satellite, into orbit. Sputnik, or "traveling companion," had a diameter of 22 inches and a weight of 184 pounds. Working sessions of the International Conference on Rockets and Satellites had just concluded in Washington, D.C., and many of the world's leading satellite experts were still in Washington when the Soviets announced their accomplishment. The convened scientists were not surprised by the launching, but they were astonished by Sputnik's weight, more than eight times that of Vanguard. Also surprising was the timing; nobody in the West had expected the Soviets to orbit a satellite so quickly.

American scientists attending a Soviet Embassy reception that evening said they were disappointed that the Russians had beaten them into space, but relieved that the pressure was off. "Now we can concentrate on doing a good job," was the prevailing sentiment. Chief of Naval Research Rear Admiral Rawson Bennett told the press that those in charge of the U.S. satellite program had never considered America to be in a space race with the Soviets and that Project Vanguard would "proceed as presently scheduled."[10] The White House issued a press release that minimized Sputnik's military importance and described its significance as primarily a propaganda defeat.

The perceptions of the American people at first appeared to mirror those of the Eisenhower administration.[11] Congress and the nation's leading scientists, however, believed otherwise. Senator Henry M. Jackson spoke for many of his fellow legislators when he described the Soviet accomplishment as "a devastating blow to the prestige of the United States."[12] The Soviet press was delighted to report "consternation in reactionary quarters in Washington," where, according to one account:

> U.S. generals and admirals and also some senators are scurrying about in bewildered confusion. Now they hunt for the culprits of the U.S. failure in the world competition of science and technology, now they try to accuse the Soviet

> Earth satellite of . . . fomenting the 'cold war'. . . . no 'investigations' will help Senator [Stuart] Symington and his ilk to conceal from world public opinion that the Soviet Union has outpaced the United States in science and technology.[13]

On that first night of Sputnik's flight, Karl Herzog, a 17-year-old Burroughs High School student, took advantage of China Lake's relative lack of interference from electrical signals to become the fifth person in the United States to report catching radio signals from the Soviet man-made moon. After enhancing his amateur receiving set with equipment borrowed from his after-school employer, Ridgecrest radio station KRKS, Herzog was able to record three distinct signals that night. At sunrise, with the aid of binoculars, he spotted the satellite as it streaked by overhead. Later in the day McLean phoned Washington to report Herzog's news.[14]

Watching Sputnik became quite a fad at China Lake. Friends meeting at the Officers Club discussed the Soviet triumph. "We ought to go shoot the damn thing down," Lee Jagiello remembered joking.[15] A group gathered on the McLeans' patio. "When we first picked out what we thought was the Sputnik, someone would say, 'No, that's not it. You've had too much to drink,'" LaV McLean recalled. Eventually someone would spot a tiny dot emerging from the sky's rim, and the group would watch in rare silence as the point of light made a horizon-to-horizon sweep across the star-studded sky.[16] To NOTS scientists, the satellite's passage was of more than aesthetic interest. Hack Wilson remembered that several scientists expressed relief that satellite feasibility was "no longer a crank theory."[17] Earlier studies in the light of the night sky had developed expertise to the point that Research Department employees studying Sputnik from the ground could reliably estimate its size and even make an informed estimate of what rocket was being used.[18]

On Sunday, November 3, the Soviets launched a much heavier artificial moon—Sputnik II, which weighed 1,120 pounds and carried the dog Laika as its passenger. Once again China Lakers watched avidly. The following Wednesday morning a group of space enthusiasts and amateur radio operators at China Lake produced time-calibrated photographs that determined the precise altitude and geographic position of the Sputnik II orbit, thus augmenting data obtained by the nation's great observatories. The local group, under the direction of NOTS physicist Carroll L. Evans, Jr., was part of Moonwatch, a worldwide amateur organization formed immediately after Sputnik's success to collect data on the passage of artificial satellites around the Earth.[19] "We were sponsored by the Smithsonian Astrophysical Observatory at Cambridge, and we were officially designated an apogee station—one of six in the world," Evans said. Apogee stations were assigned to spot satellites at their highest point of

Dr. Pierre Saint-Amand.

orbit around the earth. "We knew so little about it at first that we didn't know whether to look in the morning or the evening," he said. "We got a quick course from Pierre Saint-Amand in Michelson Lab because he knew about satellite orbits and we didn't."[20]

Moonwatch set up a control photographic station near the Los Angeles aqueduct at the base of the Sierra foothills and another station on Randsburg Wash Road. A recording and monitoring radio station in China Lake superposed timing data on a tape recording of the cameras' programmed timing. A watching station behind Michelson Laboratory was equipped with eight-power and 20-power telescopes and posts for up to 37 volunteers at a time. Evans and his volunteers entered into the satellite watch with the customary China Lake gusto, with the Moonwatch effort expanding by December to nearly 200 volunteers.[21]

Embarrassment, Then Success

Just two weeks after the Soviet artificial moon first appeared in the sky, Senate Majority Leader Lyndon B. Johnson announced that he would lead a congressional inquiry into the state of U.S. satellite research. "We have got to admit frankly and without evasion that the Soviets have beaten us at our own game," said Johnson.[22] The Senate Preparedness Investigating Subcommittee (known as the Johnson Subcommittee) began meeting in late November. In testimony before that body, von Braun noted that before 14 October his organization had been "under the constant threat of sudden extinction." On the day Sputnik first flew overhead, he said, conditions began to change. "We now know that we are here to stay, and that there is probably work enough for all of us, for all our guided-missile teams in this country."[23]

Among the programs receiving additional impetus in the wake of the Soviet accomplishment was the Vanguard program itself, which accelerated its schedule—with famously embarrassing results. In early December, the United States invited the international press to witness a launch designed to loft a three-pound satellite into orbit. But Vanguard blew up on the launching pad. The world press made this public humiliation worse by heaping ridicule on the program, referred to in Britain as Puffnik, Flopnik, Kaputnik, and

Stayputnik.[24] The next month America was ready for another shot. "Let's not make too great a hullabaloo over this," Eisenhower warily advised his press secretary. This time, however, the launch was successful. On 31 January 1958, America orbited its first satellite, Explorer I, using the Jupiter C rocket booster of the von Braun team. This first U.S. satellite, weighing just 31 pounds, was miniature by comparison with the Soviet satellites—but it was a start. Within the next two months the nation had two other successful shots: a Vanguard on 17 March and Explorer III on 26 March.[25] China Lake was not idle, either, in the race to orbit.

The eyes and ears of NOTS were also there to record the first U.S. satellite orbits. A crash program to build a signal-monitoring station resulted in China Lake's first receiving station, called a Microlock station because of its unusual frequency stability. On the evening of 31 January, members of the Test Department's Metric Electronics Branch began a round-the-clock vigil with the goal of picking up Explorer's faint but unmistakable signal and transmitting it via special radio link to the Jet Propulsion Laboratory (JPL) in Pasadena. The NOTS listeners became the first in the nation to hear the distant "beep-beep" of Explorer as it made its initial orbit. Then on 5 February, China Lake volunteers claimed the distinction of being the third Moonwatch team in the country (after Alamogordo, New Mexico, and Manhattan, Kansas) to see Explorer as it passed overhead. Local satellite enthusiasts had the satisfaction of knowing that their sighting helped establish Explorer's preliminary orbit.[26]

Tracking satellites involved new, as yet inexact science, and the NOTS team had to learn by experience to differentiate satellite signals from other similar signals. Dick Boyd, then a technician, recalled one case of mistaken identity:

> [T]here was an FM station in Santa Barbara, 107.9. . . . it must have taken six months to try and figure out where this strange carrier was coming from. There wasn't enough modulation on it to be able to identify it as the Santa Barbara FM station.[27]

Fred Ashbrook, head of the Test Department's Instrument Development Division, and other China Lakers applied their expertise to the design of the NOTS tracking station. By February 1958, Ashbrook reported to the Research Board that the tracking station, "unique in part of its design, has proven to have the additional versatility of easy tuning not present in the JPL design." He went on to say that the experience gained from the tracking program would "be of considerable benefit to the NOTS project"—the fledgling satellite that would be China Lake's entry in the satellite race.[28]

The NOTS Satellite

Bill McLean was among the earliest to capitalize on the new funding opportunities that followed from the Soviet accomplishment. He was in a good position to go after some of those funds, since the triumphant fleet introduction of Sidewinder had given an extra glow to his already shining reputation. On 10 October 1957, less than a week after the first Sputnik launch, McLean phoned Wilcox from Washington to report "that he had been doing considerable selling and that everyone with whom he had talked, including Adm. Raborn and Dr. Thompson, felt that it would be difficult to do anything more useful for the Navy than a TV-type satellite." For an estimated $200,000, McLean said, NOTS could conduct a test that would demonstrate Wilcox's idea of lofting a satellite into orbit from an F8U-3 aircraft at high altitude and supersonic speed and of getting back a useful TV signal. McLean asked Wilcox to bring "a very brief feasibility study" with him to Washington the following week.[29]

Another China Laker was also in the right place at the right time to help get support for the station's proposed satellite program. Leroy Riggs, head of the Aeromechanics Division of the Weapons Development Department, had arrived in Washington the month before intending to work in Rew (Air Weapons) under Swede Vejtasa, who had left the China Lake post of NAF commanding officer only six months earlier.

Leroy Riggs.

Riggs had scarcely moved into his new office when Sputnik went into orbit. A massive effort began to set up an accelerated space program, and Riggs' planned concentration on rocket programs went by the boards. The BuOrd part of the Navy's revitalized satellite effort was coordinated by Rex, the Planning, Coordination, and Analysis Branch, headed by Commander Frank Ault (later the author of a report that resulted in "Top Gun," the Navy Fighter Weapons School).

Riggs became systems director of aviation ordnance (Rexa), the senior civilian in Ault's office, and as a result was in a good position to observe how Wilcox's "brief feasibility study" affected Captain (later Rear Admiral) Edward A. "Count" Ruckner, deputy chief of BuOrd for R&D. As Riggs recalled:

> He called me in one day and he says, 'Riggs, this guy Wilcox from NOTS has got more gall than I have ever seen. Look at this.' He shoved a piece of paper across, and it was NOTS China Lake letterhead, half a page. . . . And Ruckner says, . . . 'Okay, you're in Astronautics now. I want you to look into this, find out what they're doing, and tell me whether I even should give them a nickel to start it.'[30]

Riggs made sure that a lengthier explanation was soon in Ruckner's hands. China Lake leaders also moved ahead smartly to brief others who could help. On November 15 the NOTS Advisory Board and the chiefs of BuOrd and BuAer heard a description of the station's plans for air- and ground-launched versions of the Naval Observational Television Satellite (NOTS I). The Advisory Board was enthusiastic about these ideas, commending the station "for ingenuity and invention in simplifying the methods of achieving satellite orbits" and recommending that NOTS I be given a high priority.[31] McLean and Wilcox then made presentations and proposals to key people in OPNAV, ONR, and the Defense Science Research Board, as well as to the chief of the Armed Forces Special Weapons Project; the President's science advisor, Killian; and Eisenhower himself.[32]

With the political way thus paved, Wilcox and others rapidly put together a more detailed feasibility study for a ground-launched version of NOTS I. This document asked for $860,000 to fund a yearlong study, including up to six full-scale launchings, of a "uniquely simple, militarily useful, four-stage-solid-rocket, spin-stabilized television satellite system," weighing 10,000 pounds. The satellite's 20-pound infrared scanning payload would be gyro-stabilized in inertial space, thus eliminating the need for a stable platform inside the satellite for a television scanner. A germanium photodetector looking out at right angles to the spin axis would scan the earth's surface from horizon to horizon in mile-wide strips. The forward motion of the satellite in its orbit would cause a parallel displacement of about one strip width for each successive strip, so that a series of orbits would provide a complete picture of the Earth's surface. This simple scanning system had the advantage of requiring no moving parts.

The study proposed to launch NOTS I from a 47-foot rail angled upward at about 70 degrees. Three different methods for putting the satellite into orbit were discussed, with the preferred method incorporating three initial rocket stages to produce an apogee, or highest point of orbit, approximately half-way around the Earth from the launch point. A fourth stage would remain spin-

Experimental NOTS I satellite vehicle on ground launcher, ready for firing, 10 June 1958.

stabilized in inertial space until NOTS I reached apogee, at which time a little rocket motor would fire to give the satellite what China Lakers later referred to as a "kick in the apogee."[33] At that point the velocity vector would also be reversed in direction, so the push at apogee would be all the satellite would need to nudge it into orbit.[34]

BuOrd authorized NOTS to proceed, but work had scarcely begun when in mid-December the bureau imposed a temporary limitation on the obligational authority the station needed to purchase the motors and launching facility called for in the November feasibility study.[35] Undeterred, the station made a second space proposal in February 1958, this time for an infrared scanning payload orbited by an air-launched system. Ruckner liked the air-launched version better, since it would allow a small, inexpensive tactical satellite to be launched from a carrier at sea into many more orbital planes than would be possible from a fixed land base.[36] The China Lake team abandoned the ground-launched version and began working night and day on the air-launched version, nicknamed NOTSNIK.

The satellite vehicle NOTS originally proposed had a total of six stages. A 5.0-inch Zuni motor, the first stage, pushed NOTSNIK up and away from its host aircraft, a Douglas F4D Skyray high-performance fighter. Then four HOTROC motors—so named because they were shaved-down ASROC motors with thinner, reduced-weight cases and added propellant load—were fired by a series of timers, with two diametrically opposite motors firing as the second stage, then the other two motors as the third stage. The fourth stage was a JATO unit designed by Allegheny Ballistics Laboratory for Vanguard, and the fifth stage was an internal-burning JPN propellant charge designed at NOTS for the purpose. The sixth and final stage was an innovative spherical rocket motor the size of a baseball retromounted for the kick in the apogee that would launch the satellite into orbit. The entire vehicle had no moving parts and used only stabilizing fins for guidance. The version the station actually built had five stages with the Zuni stage omitted.

A small, dedicated group hand-built and tested a series of NOTSNIK components in Building X, a duplicate of the A-bomb assembly building on Tinian Island that had been constructed at NOTS during the closing months of World War II. The inventive team of Jack Crawford and William H. "Bill" Woodworth devised a programmer to control the firing times of the various stages. Wiring that system to the motors was hair-raising work. "I was assembling the timer on the little retrograde rocket, and it had a nozzle that pointed right at your face," said Woodworth, who had created the timer in a special circular design to fit around the nozzle. "Just as I was hooking this last timer up to the motor igniter," he recalled, "somebody took a flash picture. I'm sure it was somebody from TID [Technical Information Department], but I died at that instant, and I do think I said very unkind things to him, which have not been documented for posterity."[37]

Others were also doing hair-raising work caused by the problem that when the propellant swelled, the grain would lose the star shape it needed to be effective. Chuck Bernard used his penknife to carve away the swollen portions of the propellant. "My arms were longer than his and not as big around, so I could reach farther, so I helped," said Don Moore, another young China Lake employee with a taste for adventure. Moore was a product of the junior professional program, an important aspect of the station's success in recruiting and keeping bright young engineers.[38] "The thing that caused me to go to China Lake, which was by far the lowest-paying offer I had, was the fact that in the JP program, they would allow you to try different things and go to work in an area that attracted you," he said. The hazardous NOTSNIK operation offered just the type of challenge Moore and Bernard relished.[39]

The confident optimism Cartwright had noted during Sidewinder tests also prevailed during NOTSNIK preparations. Ballistician Jud Smith, who with Albin Fojt performed the trajectory computations, referred to NOTSNIK working arrangements as typical of the China Lake "Tinker Toy approach," where "you bolt a bunch of things together that you think might do the job and then do it." That confidence was especially notable among the pilots, he said, remembering that two pilots joined a group observing ground tests from the safety of a G-2 Range bunker. About 20 seconds before the first stage was scheduled to fire, the whole thing blew up. Smith said the two pilots looked at each other and agreed, "This wouldn't ever happen in the air."[40]

As head of the Propellants Engineering Division in the Propellants and Explosives Department, Harold Metcalf was experiencing difficulty getting his employees paid for their work on NOTSNIK. Although official funding had disappeared, the work was proceeding. Metcalf and Gordon Draper, head of the Budget Division in Central Staff, talked to McLean about the problem. According to Metcalf, McLean nodded his head and said, "O.K.," a reaction Metcalf and Draper interpreted as agreement that NOTSNIK funding would be forthcoming. But the unfunded expenditures continued. "We went back to see Dr. McLean a second time," Metcalf recalled, "and this time he promised to go to Washington and try to resolve the funding problem. We anxiously waited for a message from him, and a couple of days later, we got a Teletype message that said, 'Unable to resolve funding problem, proceed!'"[41]

NOTSNIK workers did proceed, but in directions and with allies they could not have predicted.

Reorganization—Omen for the '60s

For the United States, the flight of Sputnik had far-reaching repercussions that included more emphasis in the nation's schools on training scientists and engineers, as well as governmental changes that elevated the Science Advisory Committee to report directly to the President, appointed a new special assistant to the President for science and technology, rearranged and reemphasized the technology-management apparatus in the Pentagon, and expanded the National Advisory Committee for Aeronautics into the National Aeronautics and Space Administration (NASA).[42]

Some aspects of the reorganization had been expected for years. In his January 1958 State of the Union address, Eisenhower expressed his view of the weapons cognizance quarrel among the military services, a daunting problem ever since the advent of the guided missile. Many of the new weapon systems, he pointed out, "cut across all services, involved all services, and transcended all services at every stage from development to operation." The Advisory Committee on Government Organization, chaired by Nelson Rockefeller, agreed. Citing "the explosive growth of technology" as a driving force behind the emergence of R&D as "a primary strategic concern," the panel recommended centralizing management of R&D with the Secretary of Defense. Eisenhower concurred, and on 3 April 1958, he submitted a reorganization proposal to Congress, recommending that the authority of the Secretary of Defense be strengthened in the areas of strategic planning, military operations, and administration. The administration eventually overcame stiff opposition from congressmen defending both their own turf and that of the military services. Eisenhower signed the Reorganization Act into law on 6 August 1958.

The act stipulated that the services no longer be separately administered, only separately organized. It also enhanced the power of the Secretary of Defense at the expense of the military departments in the areas of research and engineering. Once again, Congress and the President looked for elimination of unnecessary duplication. To help the Secretary of Defense manage his "overall direction and control" of defense R&D, the act upgraded the assistant secretary of defense for research and engineering to the level of director—the third-ranking civilian in DoD. The director of defense research and engineering (DDR&E) supervised all defense research and engineering activities and acted as principal advisor to the Secretary of Defense on scientific and technical matters. Among the authorities delegated to DDR&E was that of approving and modifying programs of the military departments and other DoD agencies. Establishment of the office has been termed a major milestone in the management of defense R&D.[43]

As the satellite competition among America's military services became more public and more intense, the President's Science Advisory Committee (PSAC), which had been meeting infrequently, began to meet twice a month, with tension at the meetings increasing with their frequency. Secretary of Defense Neil H. McElroy and Deputy Secretary Quarles concluded that DoD's science and technology apparatus was inadequate to mediate among the conflicting interests of the military services. What was needed, they decided, was a new planning agency to answer directly to OSD. Accordingly, on 7 February 1958, McElroy announced the establishment of a new Advanced Research Projects Agency (ARPA), headed by Roy W. Johnson, an executive vice president of General Electric. Johnson was outspoken in his advocacy of independence for ARPA to pursue development of space systems and antimissile missiles.[44]

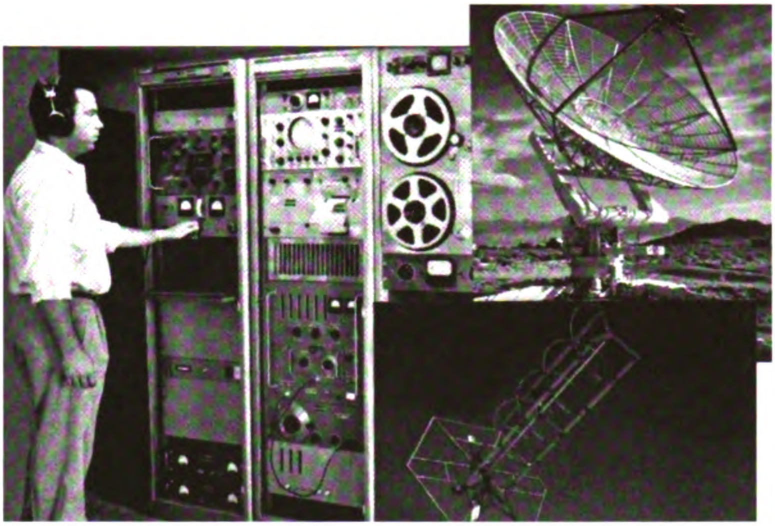
Johnson's short tenure in office encompassed a meeting with some of the desert mavericks working on NOTSNIK. Bud Sewell recalled that when he, Jagiello, Barney Smith, Riggs, and McLean met with Johnson and showed him

Wilcox' filmed chalk talk about the project, the ARPA leader's only comment was, "My God, that man can draw!"[45]

The initial purpose of ARPA was to coordinate DoD work on space projects of military value. Since the Air Force, the Army, and the Navy were independently pursuing space and ballistic-missile projects, each with its own powerful advocates, ARPA had what Herbert York, a prominent member of the Killian Committee, termed a "very confusing and politically explosive situation" to bring under control. At the urging of Killian, who saw York as the perfect man to become ARPA's chief scientist, McElroy asked York to leave his work as associate director of the University of California Radiation Laboratory and director of the Livermore Laboratory. York agreed to take the ARPA job after receiving McElroy's assurances that he would have a free hand and would be able to avoid red tape. The brilliant York was only 37 years old, his meteoric career having gotten a jump start when he landed his job at Lawrence Livermore right out of graduate school. Wilcox, who had been an instructor at the University of California, Berkeley, when York was a graduate student there, said he was "one of the smartest, most capable people I've ever run across."[46] ARPA opened for business in late February 1958, and, according to York, "played an important role in helping the Defense Department keep its house in order in the first months after Sputnik." No sooner was he in the job than he faced a barrage of funding requests, including one from China Lake.

As with Sidewinder and other pioneering projects of the Navy's adventurous desert lab, NOTSNIK had been making great progress using in-house exploratory development funds, plus monies the bureau had intended for other programs. But as the months went by, the need to obtain official increased. In mid-May 1958 Wilcox went to Washington to ask York for ARPA funds. The overburdened York, according to Wilcox, "evaluated our effort as a bit on the wild side and not likely to pay off in a real way, and consequently he preferred we didn't get into the picture at all." But eventually York agreed that the China Lakers could go ahead, with the idea that NOTSNIK might be able to gather data on the ionospheric effects of the Argus project. York's cautious support allowed the NOTS program to continue, albeit with limited funding.[47]

Project Argus, a high-altitude nuclear experiment designed to test the feasibility of an artificial radiation belt, involved the explosion of three fission-type nuclear bombs over the South Atlantic Ocean in August–September 1958. In deference to Eisenhower's determination to emphasize peaceful uses of space, the program was a closely guarded secret, as were the contributions of China Lake. The station agreed to provide five Microlock stations and three orbiting



Dish antenna, helix antenna, and portable receivers for monitoring satellite signals.

devices with radiation sensors and to meet a first-orbit deadline of 8 August 1958.[48] Vacuum-tube-trained China Lake engineers tackled the challenge of incorporating transistors, then just coming into general use, into the Microlock stations. "We worked our hearts out, but enjoyed it a lot," recalled Phil Arnold, who was responsible for the transmitter system.[49]

Wilcox asked for $400,000 from ARPA in fiscal 1958 and an additional $200,000 in fiscal 1959 to cover costs for "payloads of satellites." By July 1958 ARPA had provided that entire amount, with the Armed Forces Special Weapons Project kicking in an additional $500,000 and BuOrd assigning a further $201,000 in fiscal 1959 R&D funds to support what BuOrd called a "High Altitude Measuring Device."[50]

In the midst of intensified work on NOTSNIK in response to the demanding Argus schedule, the veil of secrecy was abruptly lifted when the 4 August 1958 issue of *Newsweek* reported that China Lake was working on "a 2,500-pound 'moon' 18 feet long and 30 inches in diameter . . . designed for reconnaissance or navigational guidance."[51] Irate officials in Washington reacted, and the station received a terse message from the Navy's chief of information stipulating that "all information concerning the air launch satellite attempts will be released by ARPA," and further that the station was authorized to answer press queries only with "no comment."[52]

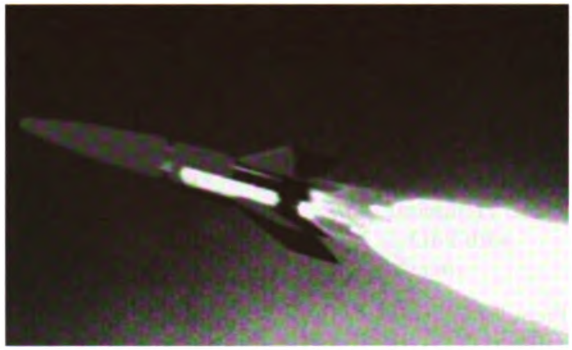
Wilcox would soon find his link to York even more useful. As important as his ARPA job was, York moved to a more significant position less than a year later. On Christmas Eve 1958 he became the first DDR&E. "We were looking for somebody older and more distinguished looking, but it didn't work out," Quarles joked when he asked York to take the job. The two men developed a relationship of trust and respect when Quarles was president of Sandia Corporation and York was director of Livermore. The new position, described by York as "a kind of super Assistant Secretary of Defense dealing with research and development," was intended to outrank the previous assistant secretary of defense for R&D. The idea was to give the position authority and status.[53]

Shortly after York assumed control, he divided R&D into six operational areas (air defense, tactical weapons, strategic weapons, communications, undersea warfare, and special projects), each headed by an assistant director who managed streamlined military-civilian staffs and made recommendations on appropriate weapon systems and projects in their areas. York's office also had responsibility for several other entities, including the Defense Science Research Board and the Weapons Systems Evaluation Group. York initially viewed the functions of his office as primarily advisory in nature, but as time passed, he took more and more decisions into his own hands. Thus the impetus for centralization that would become stronger in the 1960s was present almost from the start.[54] Establishment of the DDR&E position helped set the stage for revolutionary changes in R&D program planning and funding that would occur in the next decade, when the Navy R&D planning system would become much more formalized and centrally controlled.

NOTSNIK in Orbit—Maybe

Between 25 July and 28 August 1958, the China Lake team made six attempts to orbit the complete NOTSNIK missile and diagnostic payload. Lieutenant Commander William W. "Bill" West, Commander Hal Lang, and Lieutenant Commander S. Joel Premselaar were the project pilots. For each test one pilot took off from China Lake in a Skyray carrying NOTSNIK while the others flew along as chase pilots to observe the test. The launching pilot flew to the sea range at Point Mugu, gained speed, then pulled up into a steep climb. A low-altitude bombing system was set to release NOTSNIK when the aircraft reached a 63-degree attitude. "While others may have rolled into a split 'S' to recover, my technique was to continue skyward," Premselaar remembered. "I did not permit the aircraft to reach the vertical." Focusing on the accelerometer, he controlled the aircraft until the instrument read zero degrees, at which point the aircraft assumed the flight characteristics of a bomb at apogee. "Once the airspeed reached a safe level, I flew the machine as an aircraft."[55]

Five of these tests clearly failed, with one or both first-stage HOTROC motors either failing to ignite or igniting prematurely. The success—or failure—



NOTS Experimental Vehicle 1 in flight.

of the third orbital try is still a subject of debate whenever former members of the team discuss the project. Sewell recalled that he had been hard at work for 72 straight hours when a pilot took off to launch the third bird. As soon as the pilot reported a failure, Sewell heaved a tired sigh and headed home to bed. He was awakened about an hour and a half later by a call from Fred Ashbrook, who reported excitedly that a beep had been reported, possibly on the first orbit. "My adrenaline went up fantastically," said Sewell. However, he added, "We never did get anything other than that one beep."[56]

The person reporting that beep was Frank St. George, a NOTS engineer manning the tracking station set up by NOTS at Christchurch, New Zealand. Tracking stations at San Clemente Island and three other locations reported that few of the participants heard even that one beep, and those who heard something weren't sure of its significance. "When you've got a bunch of people on the ground that wanted it to work as badly as we wanted it to work, and when you've got telemetering gear that's turned on and you've got the usual electromagnetic static and noise coming through the receiver, you can hear almost anything you want to hear," Wilcox said.[57]

A Weapons Planning Group memo summarizing the NOTSNIK tests described the third attempt as follows:

> Ignition lag 0.1 sec. on one motor. Telemetering frequency shifted during first stage burn causing loss of contact. Missile disappeared over horizon, possible contacts at predicted time of first and third pass. ...The blowup reported by some pilots was a large smoke cloud at ignition. Objects observed to come off missile believed to be nozzle seals and perhaps some missile or fin skin.[58]

Thus the possibility exists that the unit could have completed the staging program and placed its payload in orbit. According to Dr. John Nicolaides, who had taken on the Rexa job when Riggs returned to China Lake in June 1958, the third NOTSNIK did enter orbit, but that success was never disclosed on direct orders from the Eisenhower White House. In one sense, then, NOTSNIK could be judged a failure. Support from ARPA evaporated after the failure of the attempted launches incorporating radiation monitors.[59] Even though York liked McLean and the mavericks on the desert, Wilcox said,

U.S. Navy photo, courtesy S. Joel Premselaar

Lieutenant Commander S. Joel Premselaar with F4D-1 aircraft.

Premselaar, one of three NOTSNIK pilots, poses in a publicity photo with the aircraft he used to launch the experimental satellite.

NOTSNIK "muddied his program. He had been essentially told by Dwight Eisenhower, 'Get this thing under control. I want a coherent program. I want a program that goes somewhere.' And this little project didn't fit."[60]

NOTSNIK can be seen as a success, however, in that the innovations of NOTS' first satellite served as stepping-stones for further innovations in other programs. The spherical motor designed at China Lake to place the payload in orbit saw further applications in the early 1960s when the station developed several rocket motors for NASA high-altitude research vehicles. NOTS ground stations also assisted ARPA Explorer IV and V studies, with Microlock stations at Thule, Greenland; Fairbanks, Alaska; the Azores; Christchurch, New Zealand; as well as at China Lake. The stations recorded information from 350 passes and passed that information along for further study.[61] More NOTS satellite, launching, tracking, and propulsion systems, even some antisatellite systems, followed during the 1960s. As with other station programs, all were designed with an emphasis on simplicity and flexibility.

The most important contribution of NOTSNIK, however, was that it was the first satellite to control its own spin in space by using the nutation damper developed for Sidewinder. Every spinning satellite overhead today uses that NOTS-developed technology to stabilize its flight. China Lakers can take pride in having made that essential contribution to the worldwide revolution in communication technology.[62]

18

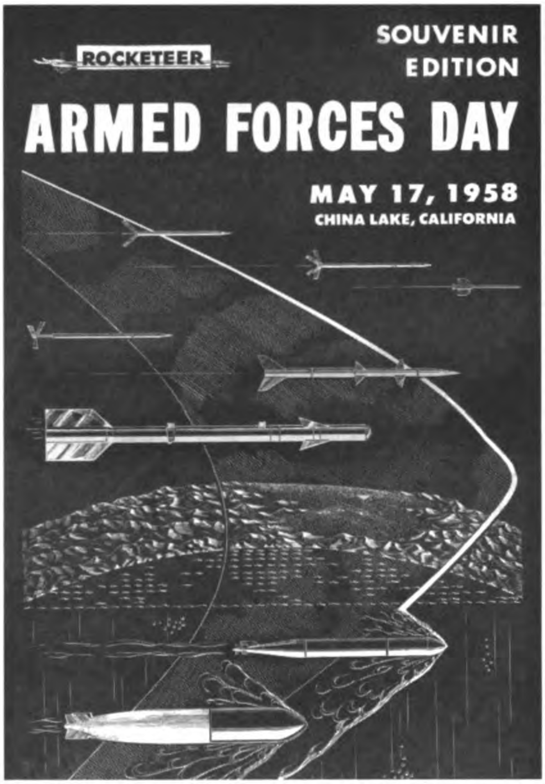
Breadth, Depth, and New Demands

By the late 1950s NOTS had matured into an organization fully capable of all phases of weapon research, analysis, design, development, integration, test, evaluation, and fleet and production support. Work reached from the depths of the sea to the far reaches of outer space. A host of new projects, notably the Walleye television-guided glide bomb and the Shrike radar-homing missile, would be important NOTS innovations in the years ahead. The Pasadena Annex took on the management of the Antisubmarine Rocket (ASROC). At the same time, the station expanded its technology base programs in areas ranging from properties of metals to undersea propulsion and continued its emphasis on support for the fleet, notably in one of the most dramatic events in China Lake's history—the combat debut of the Sidewinder missile over Formosa Strait.

Visions for the Future

During his tenure as the station's ninth commander, Captain Bill Hollister would see completion of Hangar 3, the Propulsion Research Laboratory, the Skytop facility for testing large solid-propellant motors, and Polaris underwater launching sites at San Clemente Island, as well as ground breaking for a 500-unit Capehart housing project. Under his command the station would tackle challenging technical projects to be used from the lower depths of the ocean to outer space. Although Hollister did not directly participate in fostering the technical projects, he offered quiet support much appreciated by McLean and other China Lakers. "There were no arguments about that's my cognizance, this is yours," recalled Hack Wilson. Furthermore, as Newt Ward observed, the fact that Hollister did not expect to rise in rank "made him a better CO because he didn't have to worry about it."[1]

As the community prospered under Hollister's low-key leadership, conventional warfare projects were robust, following McLean's and Ashworth's earlier success selling the concept in Washington. Foundational and applied research funding expanded until 25 percent of the station's professional staff was



Courtesy Maturango Museum, Ernest George estate

Rocketeer front page illustrating NOTS weapons in fleet use from sea to sky.

working on applied research projects. McLean continued to pursue his vision for China Lake's technical future. In July 1957 the Research Board met in two special planning sessions that brought out ideas ranging from arming submarines to designing new air-to-ground attack weapons.[2] A 12-page thought piece for the NOTS Advisory Board summarized these ideas and posed the rhetorical question, "Is the present role of NOTS in the development of Navy weapons the optimum one?" The station's strength "derived not so much from the existence of the primary functions of planning, research, development, and test, as from their mutual interaction," the paper pointed out, listing "Psychological Strength Factors of NOTS" as the concept of the military-civilian team, the "lack of a profit motive, as compared with much of industry," remoteness from Washington (a distance that "promotes originality of thought"), and desert living "attractive to the independent type of individual."

Station leaders worried, however, that national trends would result in disturbing changes for NOTS. "The policy of Congress for some time has appeared to favor the industrial conduct of defense research and development, as against the same work being done by government agencies," said the paper, suggesting that in deference to changes in the BuOrd approach to weapon development, NOTS could function both as technical manager for BuOrd contracts and as technical consultant to the bureau. A suggested role as a center for weapon system exploration with an emphasis on planning and exploratory research and development of weapon systems either in-house or by NOTS-supervised contract was one that would come to pass during the 1960s.[3]

The following February, McLean again put his thoughts on paper in response to a BuOrd request. Looking six years into the future, he envisioned the principle of deterrence as well established, with the important belligerents having "gained sufficient destructive power to make all-out war intolerable." The nation's defense would instead "operate with relative safety under accepted rules for the limited application of force." Weapon-development groups, he said, needed to "distinguish themselves in the advanced areas of research so that no question can arise in the minds of a potential adversary as to our ability to include new techniques in our weapons." He forecast that most productive areas of research and development for conventional weapons would be in search and detection capabilities, identification of targets, reduction in size and cost of guided weapons, and reliability. He suggested a focus on exploration of the atmosphere and the ocean, particularly in materials, propulsion technology, and methods of adapting the products to the environments in which they would be used.[4]

The thinking of the nation's leaders had changed too. "The need for conventional weapons is being emphasized by all branches of the Armed Forces because of the current trend in worldwide thinking that any possible future hostilities would be on a limited war basis rather than all out nuclear attack," Senior Experimental Officer for Air-to-Air Weapons Bill Moran told the Research Board. "It is not proposed that the special weapons capability be reduced, but we need, in addition, a conventional capability that is really effective."[5] Moran had experienced that need the hard way during the Korean conflict and had already started NOTS on a new weapon development as a result.

Antiradar Weapon Needed

Station thinkers from McLean down spent a lot of their time dreaming up concepts to meet future defense needs. But responsiveness to the immediate needs of the operating forces had to be considered first. The sharp military men assigned to the NOTS Experimental Office were often the first to articulate such needs; they could turn to hardheaded realists like Barney Smith and Frank Knemeyer to meet these needs as they arose.

Several generations of important antiradiation weapons can trace their origins to just such military and civilian teamwork. Shortly after he arrived at NOTS for his second tour in July 1955, Moran began pushing NOTS technical people to find a solution to a problem he encountered in Korea. He wanted something that would allow a pilot to hit his target without himself becoming a target "painted" by enemy radar. "Bill pestered us and pestered us to divert manpower from something else and work on an antiradar missile. The official Navy policy at that time was that Corvus would solve all their antiradar problems," Newt Ward said. "Bill repeatedly expressed his strong opinion that Corvus would not solve the tactical problem because of its complexity and cost." Not only did Ward not pick up the challenge at the time, but McLean was apparently also skeptical that an alternate solution could be found.[6]

Barney Smith, who had become head of Code 40 in April 1958, was more receptive. Moran's and Smith's offices in Michelson Lab were just across the hall from each other, and one day Moran visited Smith to pose the problem. "What can you do to blind that gun-directing radar?" Moran asked. "It struck us both simultaneously that the radar beam itself was an excellent homing signal," remembered Smith. "Forthwith, I put a team together to work on an air-launched, antiradiation missile."[7] The team's leader was Lee Jagiello, head of Code 40's Aeromechanics Division.

Jagiello and his group put together a missile that was as simple as possible, with a beefed-up Sidewinder servo and a passive radar seeker and control system. Albin Fojt's simulations on the REAC showed the feasibility of using a bang-bang servo. "Lock on their gun or missile-directing radars and get close enough to damage the antenna, that's all you had to do," Jagiello said. "We conceived the idea of the pilot pulling up to a certain angle, predetermined by where the range of the radar is, and launching. The propulsion stage was very short, and from then on it was just a free-flight missile and it would come close enough so you damaged the radar antenna." The first test proved the feasibility of the concept.[8]

When Moran and Jagiello went to Washington to present the concept to Count Ruckner, they found a familiar ally. That was when Leroy Riggs was on his yearlong tour with Ruckner, so Riggs was in the right spot to help Moran. According to Riggs, Ruckner's reaction was, "I'll give you $250,000. You go demonstrate to me in a year that you can do something in the Sidewinder kind of spirit." Not only did Riggs help out in Washington, but he also was in the right spot when he returned to China Lake, taking over program leadership from Jagiello for what was at first called Cobra after the deadly snake. In 1961 the redesigned missile would be renamed Shrike after the bird, which according to folklore would peck out its enemy's eyes.[9]

Riggs didn't manage the program for long because he accepted the position of head of the Aeromechanics Division. But his direct involvement with the missile continued. He made numerous program presentations in Washington and observed Shrike's first use on board *Ranger* (CV-61) off the coast of Vietnam in 1966.[10]

Knemeyer, who would become the head of Code 40 with Smith's departure in 1960, was the assistant head of the department at the time Moran, Jagiello, and Riggs sold Cobra to Ruckner. After the station got Ruckner's go-ahead, Knemeyer remembered that Langthorn Sykes (then head of Code 40's Fuze Branch, but destined to become the missile's program manager in 1960) said, "Well, now we've got to start shoveling sand." Amazed, Knemeyer asked, "What do you mean?" Sykes' answer was, "We have just proved the technical feasibility, but we don't have any on-the-shelf parts to go in this. Everything's got to be developed from scratch." That made the development program rougher, of course, "but we got through it all," Knemeyer said.[11] In the latter half of 1958, a Code 40 team built two antiradar missiles in hopes of proving that a missile as small as eight inches in diameter could home on a radar. "There were many good technical people around that thought it was not feasible," said D. Jack Russell, one of the group of bright young engineers and technicians who were getting their first experience with guided missiles on the feasibility study.

After the team established overall missile design parameters from analog simulations, the Cobras were assembled from existing components wherever possible. Many pieces were tooled in the Michelson Laboratory machine shop, then hand-fitted. As the missiles went through final checkout in the lab, the Test Department set up an SCR-584 fire-control radar on Charlie Range as a target.[12] The team loaded the first missile onto an F3D aircraft for captive flights and the first firing. "Something in this missile obviously failed because there was no indication of homing on the target," said Russell, who flew in the F3D's second seat for that firing.

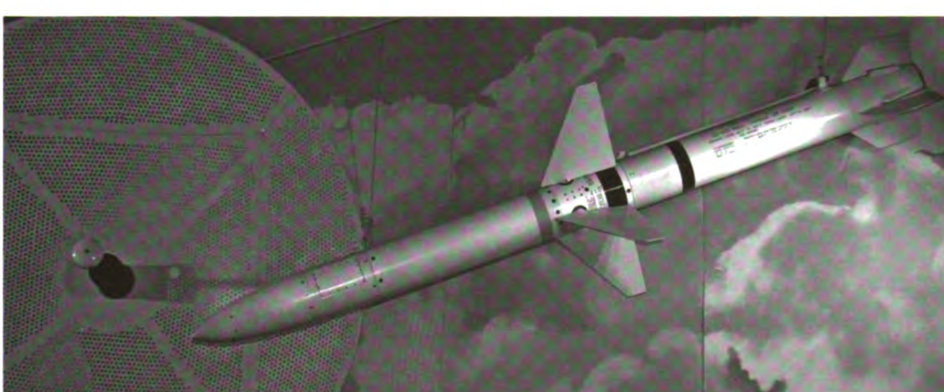


Photo by the author

Shrike missile on display at U.S. Naval Museum of Armament and Technology.

The group checked and double-checked the second missile before sending it aloft. The pilot fired in the general direction of the target radar. "With binoculars we could see that it was homing toward the target," Russell remembered. "Although it impacted roughly 200 feet from the target, it succeeded in demonstrating the concept." That firing paved the way for an advanced development program wherein Russell and others on the enthusiastic young team had opportunities to try out their ideas to improve component design for a low-cost, 8-inch-diameter, antiradar missile.[13]

Shrike, a China Lake technical development from concept to fleet introduction, became the first missile to provide the Navy and the Air Force with the capability to detect, identify, and destroy or suppress hostile radars under all weather conditions. The missile also helped U.S. pilots because enemy radar operators spotting U.S. planes armed with Shrike would turn off their radars, thus leaving the target open for attack.

As Ward commented later, history proved Moran to be "wiser than most of us believed back in the 1950s."[14] Thanks to Moran's persistence and China Lakers' responsiveness, defense-suppression weaponry became an essential part of every aircraft's armament. "You had a set of folks saying there is no requirement for such a device," Moran recalled. "That's hard for some of the attack pilots of today to understand that anybody ever made such a statement."[15] During the service life of Shrike, some 22,000 missile systems were manufactured, with more than 9,000 of these systems used in combat.

New Challenges for McLean


U.S. Navy photo LHL 033035

McLean receiving his gold medal from President Dwight D. Eisenhower with Secretary of Labor James B. Mitchell looking on.

By the late 1950s, McLean was at the height of the fame he earned as the inventor of Sidewinder. In December 1956 at a gala dinner at the Waldorf-Astoria Hotel in New York City, CNO Arleigh Burke presented McLean with $25,000—the largest incentive award a civil servant had received to that date. In remarks during the dinner, Bureau Chief Withington said McLean's efforts had already saved the federal government an estimated $46 million through economies in development and production. The following April the California State Legislature presented McLean and LaBerge with special scrolls in honor of their contributions to Sidewinder. In January 1958 Bill and LaV McLean and their son Donald traveled to Washington, D.C., where President Eisenhower presented Sidewinder's inventor with a special gold medal award, one of the first of its kind, for "exceptionally meritorious civil service."[16]

McLean's unpretentiousness in the face of public praise may be glimpsed through an anecdote family friend Polly Nicol remembered in connection with the gold-medal trip. Young Mark McLean was staying with the Nicols while his parents were in Washington, and he and his friend Jim Nicol found some tar paper in the alley that made fine sailplanes. When one of the pieces of tar paper landed in a neighbor's yard, the neighbor called China Lake Security (the community's in-house police force) to complain. An officer showed up to question the two youngsters. "When Mark gave his name, the security officer said, 'Is your father technical director?' Mark says, 'I don't know,'" Polly Nicol recalled. "I thought that was a priceless remark."[17]

No doubt one reason why McLean retained his modesty was that accolades didn't seem to be important to him. He was busy thinking about the next technical challenge—undersea transport and attack vehicles. He had been fascinated with the underwater experience for years, with his experiments with homemade wet suits (which he referred to as "dry suits") often

"Memories of Us" CD, China Lake Museum Foundation

Bill and LaV McLean trying out dry suits at the station pool.

involving a long dunk in the station's Olympic-sized indoor pool for LaV or one of her friends.[18] Now his post-Sidewinder assessment of what the Navy needed convinced him that operating underwater was the best way to avoid enemy attack.

McLean thought designers of existing antisubmarine warfare systems couldn't see beyond the traditional miniature subs. He visualized an application of aerodynamic design principles to a small submersible vehicle flying through the water and engaging enemy submarines much as a fighter aircraft would in the air. Don Moore, who had become a trusted associate as the two worked on dry suits late at night in McLean's garage, was one of a small team of NOTS employees who began to think about small submersible vehicles.

In the early 1960s, these ideas would develop into the small two-man submersible vehicle named Moray, the cable-controlled underwater recovery vehicle (CURV), other submersible craft, even explorations of the concept of undersea bases. As with NOTSNIK, the lack of funding for these new challenges didn't deter McLean. "You had no problem with this, because when Dr. McLean wanted something done he would ask you to do something and he would give you the money to do it," said Ernest G. "Ernie" Cozzens, another can-do China Laker contributing engineering expertise to station projects.[19]

ASROC—the Antisubmarine Rocket

Even as creative individuals at Pasadena helped develop the types of hand-built undersea projects McLean relished, Pasadena Annex leaders tended to follow the more traditional approach of identifying needs, then selecting contractors to develop the solutions under annex technical direction. In June 1956 Donald W. "Don" Steel, who had been head of UOD since November 1954, left to return to his alma mater, Case Institute of Technology in Cleveland, Ohio, to head a nuclear research laboratory. Steel, who had been a 1952 recipient of the prestigious Sloan Fellowship at MIT, was admired in Pasadena as a straight-thinking leader in the classical mode.[20] To replace him as head of UOD, McLean selected Douglas J. "Doug" Wilcox. The job represented a special challenge for Wilcox, since his direct management of the ASROC program had begun only a month earlier.

Rocketeer, 12 November 1955

Donald W. Steel.

Wilcox impressed McLean and the Research Board with a fact-filled report as he took over ASROC leadership. His report described two types of airframes: a clamshell type similar to that for Phase B RAT and a tubular assembly that would slide off the rear of the payload at separation. To save time and money, the EX-2A torpedo would be used without modification. A second torpedo would be designed later for use against fast, quiet submarines of the *Albacore* class. As for design of the atomic depth bomb version, which had been assigned to Los Alamos pending an LASL decision on final specifications, the Pasadena Annex was proceeding with a tentative casing design based on available information. The report concluded by saying that cooperation was excellent "across the board" and that the program was ahead of schedule.[21]

U.S. Navy photo

Douglas J. Wilcox.

Wilcox had previously headed Pasadena's Development Division (RAT), in which he was responsible for development of torpedo components and ballistic missiles, as well as operation of UOD's field ranges at Morris Dam, Long Beach, and San Clemente Island. His career at NOTS had begun in 1948, when, newly graduated from Cornell University, he joined the annex as a new professional (Pasadena's equivalent of the JP). He became head of the 500-person UOD before his 35th birthday.

To his new responsibilities Wilcox brought the ambition and enthusiasm of youth tempered with a pragmatic management approach that would serve him well in running what rapidly became a complex program that relied more on contractor expertise than China Lakers traditionally liked. At the height of the ASROC development, he was in charge of a program encompassing some 1,800 people in diverse professions and trades from more than 30 major government and industrial organizations. The station had technical direction and design cognizance, with Minneapolis-Honeywell assigned as the prime contractor. To organize the station's work on the multimillion-dollar program, Wilcox established task teams and assigned them major system components.[22]

Since the ASROC program ultimately involved most of the technical departments at China Lake as well as at Pasadena, Wilcox spent at least a day a week on the desert working to keep communication lines open. Pasadena was responsible for work on the nuclear depth bomb and the airframe, plus the integration of all systems; the Rocket Development Department took on responsibility for the rocket motor; and AOD built the electronic separating device and integrating accelerometers. Much of the testing was done at China Lake, where the isolation of the desert helped ensure secrecy.

Although Wilcox was trained as a mechanical engineer, he was the first to recognize that his administrative skills were the primary reason for his meteoric rise. To help with the technical decisions, he moved trusted colleagues with engineering expertise up into positions of increased responsibility within UOD. He promoted Charles G. "Chuck" Beatty from leadership of the Simulation Branch, Guidance and Control Division, into the division-head job in the Torpedo Development Division. Bud Kunz moved up within the RAT Development Division into Wilcox's former division-head job.

Wilcox also installed a technical alter ego on the department staff—Wallace E. Hicks, who had been head of the Analysis Branch in the Development Division. "Wally was our technical whip," recalled Jim Campbell, a longtime UOD employee. "Doug, I think, tried to handle the big picture. He interfaced with people in China Lake or back in Washington . . . and if he needed to make sure that the efforts of this group were directed, then he delegated to Wally Hicks the responsibility of keeping the technical excellence and purity of the place intact."[23]

Wilcox attributed his success with the ASROC contractors to the simple maxim, "Contractors Are People." If contractors "are committed to the same goals that NOTS wants to achieve, there is a good chance that the program will move ahead in the right direction." He stressed the importance of expertise, exhorting his employees to be "intelligent customers," a phrase echoed in the "smart buyer" emphasis of later decades.[24]

The involvement of many organizations in the ASROC development made in-house testing critical. About a year into the program, test results showed that the stabilizing fins on the parapack weren't deploying properly. Jim Jennison and his specialists in the Product Engineering Division solved the problem, but only through a redesign of the airframe, with a clamshell design replacing a tubular airframe. Hack Wilson later pointed to this design as an example of the imprecision of the development process. "I don't know how much junk we must have put onto the pile as a result of making that decision," he said.[25]

Jack Crawford and Bill Woodworth, who had invented applicable technology for the Mk 16 fire-control system, contributed the weapon's controller, an ingenious device that determined when to terminate thrust (range control) and when to release the payload (torpedo or nuclear depth charge) from the airframe. To allow the payload to enter the water at a velocity slow enough to keep it functioning, the clamshell airframe needed to release the torpedo at the precise time to let it parachute to the surface. A magnetic integrator invented by Crawford provided a signal from the weapon's axial accelerometer, kept track of the velocity, and at the right moment blew open the clamshell to release the torpedo.[26]

As with any new device, the magnetic integrator needed testing and tweaking, a process that made recovery of test missiles critically important. Crawford vividly recalled one test where the airframe didn't open and the missile crashed through the deceptively dry surface of the China Lake playa. After a Public Works crane dug down through about 15 feet of muck, Crawford and others involved with the test had to climb into the hole and sift through the muck to find the pieces needed to assess test results. By the end of the day, the team concluded that another unit needed to be built. After three days of round-the-clock effort, the team completed a new unit and fired it successfully. "It was one of those real exhausting operations," said Crawford. "Very exhilarating to do if you don't do it very often."

Another aspect of the water-entry problem required ASROC designers to terminate motor thrust to slow the rocket down as it neared the end of its journey. The first idea was to blow off the nozzle end, thus theoretically releasing pressure in the tube and stopping the motor from burning. Experiments soon showed that a sudden increase in area at the back end of the motor actually caused a dramatic, if temporary, increase in thrust, along with a kick sufficient to crumple the airframe and destroy the payload. The next design featured an opening at the front of the motor slightly larger than the opening in the nozzle at the back. The idea was that when this hole was exposed, most of the hot gas would rush out the front rather than the back, thus causing the motor to fall away. Unfortunately the backward thrust moved a small metal plate called a spider (designed to hold the propellant grain in place) just enough to block the hole. With the hole at the front suddenly smaller, the motor became forward-propulsive again, and rammed the back of the missile before falling away.

Repeated experiments and adjustments overcame the problem, but not before a still-smoldering motor hit the ground with enough force to fill its front hole with dirt. With the front plugged, the motor took off again and flew off across the range for several miles, much to the dismay of the test crew. In another incident that Crawford called "a real illustration of how the smallest things have unexpected consequences," a metal fairing inserted between the airframe and the payload to reduce the drag was "value engineered" during the preproduction design phase to a fairing made of molded rubber. When the NOTS team began ballistic firings to establish ASROC's flight characteristics, the test engineers discovered to their surprise that the rounds were falling short. "Everybody thought our programmer must not be working right, that something had happened," Crawford said. "It turned out that that rubber piece at transonic speeds folded open, and it stuck out in the air and acted like a drag brake and was slowing the missile down." The metal fairing made an immediate reappearance.[27]

The ASROC program differed from the Sidewinder development, both in its design approach and in the size of the in-house and contractor team involved. Still, Wilcox appreciated McLean's advice and applied it wherever he could. For example, when Wilcox worried aloud about ASROC's high potential for connector failures, McLean gave him a Zenlike suggestion: don't solve every technical problem, but go around it. When Wilcox asked for clarification, McLean explained that the way to deal with connector problems

U.S. Navy photo, China Lake archives

Norfolk (DL-1) launching a Mk 44 Mod 0 lightweight torpedo from the first shipboard ASROC system, 1960.

was to eliminate the connectors. After mulling over this advice, Wilcox decided to stipulate that all connections be hard-soldered at the factory. As a result ASROC was remarkably free of connector failures. McLean "would never attack a problem technically head on," Wilcox said, adding that "it is amazing how many times you think you need something or some piece of equipment when in fact if you do it a little bit differently, you avoid the problem."[28]

The station subjected ASROC to a series of firings at China Lake, San Clemente Island, Long Beach, and Morris Dam, with the version for the AEC fired from the Naval Ammunition Depot, Hawthorne, Nevada, into nearby Walker Lake.[29] The program interested the highest levels within the Navy. Burke himself requested that the system be ready for fleet introduction in two years. Wilcox got permission to take three years, but, he said, "We were so 'can do' that we actually built, fabricated, constructed, demonstrated, and got it into production in under three years."[30]

The weapon reached initial operational capability in 1961 and was installed on cruisers, frigates, and destroyers, where it became the Navy's principal shipborne antisubmarine weapon. The follow-on Vertical-Launch ASROC is still in the fleet today.

Walleye—an Eye for Precision

China Lakers relished the freedom to start with an idea, not a requirement. As Jack Crawford said, "If you write a firm requirement first, you may very well build things that are so costly you end up not being able to afford them." That freedom and the emphasis on adapting existing technology to innovations were important to the development of Walleye, a television-guided glide bomb that became the nation's first precision-guided antisurface weapon.

Unlike ASROC, which rapidly grew into a large program encompassing many organizations that needed forceful matrix management to ensure compatibility of all parts of the system, the Walleye development was much more in the Sidewinder mode. A few obsessed engineers accomplished nearly the entire initial Walleye development, with the warhead and the fuze developed by others at NOTS. The advantage of that integrated approach, Crawford pointed out, was that "no matter which piece you were working on you were rubbing elbows continuously with the people who were working on all the other pieces." He explained further:

> With the matrix approach, each group has to have a set of specifications for what they are building so that when it's all put together, each of these pieces will work and they will play together. Since these specifications are generated before

> the development is started, you don't know how difficult they will be to meet. Well, that means you may just bust your tail meeting some little requirement that really isn't too critical for the other guy. If you only knew that, giving up a little on the requirement would help you a great deal. When one group is doing all the tasks with everyone in close proximity . . . you get those trade-offs being made very fast, daily, and you end up with a much more integrated design. . . . There's a point at which you can't do it, because it's too big for one group to do that. But on anything that's modest size, it's a very powerful way of approaching it.[31]

The Walleye program grew from the need to develop a weapon that could passively home on and destroy large land targets and ships while the launching aircraft got out of harm's way. Crawford and Woodworth began thinking about a television-guided glide bomb in 1956, after concluding that unguided bombs had been developed about as much as they could be. "The bomb director intrigued us," Woodworth said. "How do you do accurate direction of weapons, air-launched weapons, to surface targets? And I remember we talked about this, on and on and on and over again."[32]

Crawford was familiar with a historic 1934 memorandum written by Vladimir Zworykin, director of the Electronic Research Laboratory of the Radio Corporation of America (RCA), to RCA President David Sarnoff. Zworykin proposed a "flying torpedo with an electric eye," television guidance in other words. That and other information in an RCA book about early television "provided invaluable background to us to avoid many pitfalls," Crawford said. He and Woodworth were also aware of several television-guided weapons that had been tried and then abandoned. Bat, the pioneering radar-guided weapon of World War II, also had a TV-guided version that used an RCA iconoscope camera. The Germans had tried a similar weapon. A third, more recent experiment, called Automatic Video Optical System of Edge Tracking (AVOSET), had been conducted with BuOrd funding by Frederick C. "Fred" Alpers and others at the Naval Ordnance Laboratory, Corona.

These early attempts to use television in weapon applications had hard mounted the camera to the airframe so that maneuvers inevitably disturbed the picture. Another related problem was that the TV picture, not being three-dimensional, couldn't provide reliable information on the direction the weapon was going. Crawford and Woodworth agreed that both problems could be solved by adapting gyro-stabilization and proportional-navigation technology developed for Sidewinder.

The two engineers' temperaments and abilities also gave them tools they could apply to the project. Crawford, according to Woodworth, had "a

Newt Ward presenting commendations to members of the Walleye team. From left are Don Wheeler, David Livingston, Jack Crawford, John Hemiup, Bill Woodworth, and Ward.

perception of physical reality that many people have lacked. In this way he was very similar to McLean. Jack could immediately point out, after we had looked at why these other systems didn't really work, what their problem was."[33] Woodworth added considerable experience with trackers, as well as problem-solving ability and willingness to look at fresh approaches.[34] Others contributing ideas from the start were George Lewis (who shared the patent on the basic scheme with Crawford and Woodworth), Bob Allen, David Livingston, and Bob Cunningham.

Norman Kay, a friend of Woodworth's who worked on the Sidewinder team, contributed pertinent information almost by accident. Fascinated with the relatively new phenomenon of television, Kay experimented in his spare time with an iconoscope camera he had built. One day he reported that he had created a circuit that allowed him to track objects moving in the picture, a person walking down the street for example. When Woodworth saw a demonstration of the device, it strengthened his conviction that a simple, reliable guided bomb could be made by combining television and Sidewinder technologies.

After much thought and conversation, Crawford and Woodworth wrote a January 1957 memorandum to Newt Ward. The memo described "a possible means of guidance for an air-to-ground TV guided missile" that would combine the automatic-tracking features of a target seeker with the remote guidance provided by television:

> In a conventional TV guided missile, an image of the target (assumed to be an object on the ground) is transmitted to a receiver at the control point (the operator in the releasing aircraft) and control signals are transmitted to the missile to guide it to the target. Under ideal circumstances this system should produce excellent results. The system is, however, vulnerable to jamming of either the TV or the control signals and requires an operator to guide the missile all the way to the target. . . . the way to overcome those weaknesses is to give the TV missile the intelligence to track the target itself, once the target is pointed out to it.[35]

Ward was enthusiastic, but when he took the idea upstairs, McLean was dubious that the automatic tracker would work. McLean did agree, however, that Ward could provide exploratory-development funds for a feasibility demonstration. He suggested leaving in the provisions for a radio data link in case the concept didn't work. "Bill was smart enough to realize that you don't always know whether things will work and so you ought to let people give it a try," said Crawford, paraphrasing that approach as "you've got to let people be wrong, because sometimes they are not."[36]

With the money from Ward and much encouragement from John Gregory, head of AOD Development Division 1 (Bomb Directors), the small Walleye team got started. So involved were Woodworth, Crawford, and the others in thinking about the technical challenges ahead that they gave little thought to the necessary administrative procedures. Woodworth said Gregory "probably smoothed the way for our work more than I would ever realize at the time."

For most of the following year, the group built breadboard trackers and experimented with television techniques. Building a small, reliable solid-state television camera was not an easy feat in an era when the transistor was just coming into common use. The TV cameras on the commercial market were "big, clunky things," Woodworth said. "And we had to develop a television camera that could be mounted in a gimbal. So we made that, really, the first line of endeavor. And there were a number of significant technical accomplishments that I was always kind of proud of that subsequently got absorbed by industry."[37]

Once the basic ideas proved feasible in laboratory models, Crawford said, "it was a matter of pulling those ideas together and testing the result in the cheapest vehicle we could figure out a way to make." The team strapped two Sidewinder servos together inside a piece of oil well casing for the outside shell, added two cylindrical air bottles for power, then put a gyro-stabilized seeker at the front. The idea was to try out the vehicle to see whether it could operate from a standard, unmodified television input. By 1958 that vehicle had been assembled and mounted in a helicopter for flight testing in what Ward termed "Project Fetch." Even though Ward had supported the project from the start, he was amazed when the camera, mounted on a helicopter, homed all the way as the chopper approached the target bridge. "The thing flew, and it worked," Crawford said. "Then we got down to the details of exactly how should we build something the services could use."[38]

Walleye's subsequent triumphs over technical challenges and Washington politics led to fleet introduction in 1967, when the weapon delivered its innovative linear-shaped-charge warhead to the target with pinpoint precision. Subsequent enhancements included an extended-range data link, which took advantage of developments in digital technology to allow the pilot to control and update the aimpoint after launch and which became the technical basis for all U.S. data links. The weapon was used successfully in Vietnam by both the Navy and the Air Force. Perhaps more to the point for this book, the early development of Walleye well illustrates the environment within which the China Lake mavericks of the 1950s were able to create new concepts that dramatically influenced succeeding generations of weapons.

Rocket-Propelled Ejection Seat

Another type of work assignment in the late 1950s used station propellant expertise to save pilot lives. In 1956 CNO Burke was distressed to learn from the Naval Aviation Safety Center at Norfolk that during the previous year alone 15 fatalities were caused by live emergency ejections from naval aircraft at altitudes of 1,000 feet or lower. The seat catapult failed to shoot an ejecting pilot high enough for proper parachute deployment. Burke gave BuAer responsibility for finding a quick solution, and BuAer in turn called on BuOrd for help from its explosive and propellant experts. McLean suggested that NOTS could do the work.

By February 1957 Herbert M. Neuhaus, a consultant to the Propellants and Explosives Department, and Norman L. Rumpp, head of the Mechanical Process Branch, were working on the task, Neuhaus as project coordinator in charge of investigating feasibility and preparing a proposal and Rumpp as project engineer for the development phase. When Neuhaus began looking at the problem, he realized that among the "welter of misinformation" available, only one thing was clear: "no one knew what had to be supplied or what goals had to be met."

Neuhaus later reported on his difficulties in getting the information he needed. The organizations involved, starting with BuAer itself, perceived NOTS

Demonstration of rocket-propelled ejection seat, 1960.
The seat ejects an anthropomorphic dummy from a SNORT sled, then flies through the air high enough for a parachute to open and carry the dummy to a safe landing.

as operating in an area that was beyond its proper scope. Consequently, said Neuhaus, "No one wanted to commit himself." The China Lake team pressed on, visiting aircraft manufacturers to obtain seat dimensions and weights, catapult locations and attachment data, ejection accelerations and onset rates, aircraft speeds, and empennage (tail assembly) dimensions. From the Naval Air Material Center in Johnsville, Pennsylvania, came technical parameters and drawings of the catapult to be replaced. From the Navy Parachute Unit at the Naval Air Station, El Centro, California, came information on the standard parachute to be used and the maximum velocity and minimum height needed to ensure safe deployment of the chute. Finally pilots at NAF Norfolk reviewed the proposed parameters and agreed that they appeared sound.

Once Neuhaus had this information, he was able to arrive at preliminary specifications for a new rocket-propelled ejection seat to be named RAPEC (Rocket-Assisted Pilot Ejection Catapult). The RAPEC system could be activated when a pilot needed to bail out of a disabled aircraft on or near the ground. Since a RAPEC-equipped seat could catapult the pilot up 200 feet or more, he could gain the altitude necessary to allow his parachute to deploy and float him safely earthward.

In June 1957 BuOrd accepted Neuhaus' specifications. Funding arrived that September, and BuAer assigned the first installation to the Douglas A4D aircraft. Richard J. Zabelka, a mechanical engineer who had just completed his first year at China Lake, was assigned the overall design work. Also contributing expertise were members of the Mechanical Process Branch including Cecil A. Glass, who designed the system's first booster stage, and David A. Colpitts, who contributed the design of the RAPEC ignition system. Experienced machinists in station machine shops constructed prototypes for the pioneering system.[39]

The shape of the igniter's pressure/time curve was of prime importance since the usual igniter pressure spike could break the pilot's back. Dr. Ronald Henry and Dr. William Finnegan of the Research Department's Chemistry Division had just invented a new synthetic plastic, polyvinyltetrazole. "We were happy to find a use for our new exotic plastic," recalled Bill McEwan, by then the division head. The division supplied a sample to Hercules Powder Company, which had a contract to make the squibs. "When the ordnance specifications were finally written," McEwan said, "it was discovered that the only supplier in the whole world was the Chemistry Division at NOTS."[40]

By fall 1958 successful tests on SNORT had catapulted a dummy strapped in an ejection seat 225 feet into the air and had seen the seat safely parachute back to earth. "Another China Lake First—Successful RAPEC Tests Pave Way for All-Military Use of Pilot Ejection System," read a *Rocketeer* headline.[41] With the success of the initial tests, major aircraft manufacturers Douglas, Grumman, Chance Vought, North American, and Martin began projects incorporating RAPEC technology into seat-ejection systems.[42]

With the lifesaving RAPEC project, the station had again demonstrated the benefits of crossing department lines to use the best skills and tools available, regardless of nominal job responsibilities.

Operation Pop-Up

While McLean and his helpers began new work on conventional systems, the station was also contributing to the nation's deterrence arsenal, notably to the Polaris program. Although NOTS' most significant contribution to Polaris was undoubtedly its central role in earlier ballistic-missile feasibility studies, the station also made important contributions to Polaris launching technology and underwater propulsion systems, both areas that involved daunting technical challenges.

As he had with earlier strategic studies, Polaris Technical Director Levering Smith turned to China Lake for its sharp technical skills when he needed help with propulsion technology. This time he gave the Chemistry Division the responsibility for keeping a close eye on Aerojet-General Corporation's propellant development and formulation. After a large mixer at Aerojet's Sacramento plant exploded, NOTS chemists were able to show evidence that the Aerojet composition was unstable. Aerojet then reformulated its propellant.[43]

The station tackled the major problem of getting Polaris to the surface. Nobody knew how an underwater-launched missile would function as it sped up through 50 or more feet of water and broke the surface of the sea. Would Polaris remain on course? How would the missile be affected by surface waves? Would it go high enough into the air for its engines to ignite? Would an oscillating bubble give away the launching submarine's location? Smith also wanted Polaris to be able to launch surfaced at sea, in port, or in water too shallow to submerge.[44] These challenges were made to order for Bill McLean. Many associated with Polaris believed that the technical difficulties were severe enough to necessitate ship launch, but McLean and others at NOTS had the opposite view. The "off-hand opinion of personnel at the Station," he told BuOrd, was that "the difficulties of launching from underwater were less than those involved in launching from a surface ship under the normal conditions of weather and bending and twisting of the ship."

NOTS engineers had already demonstrated that a missile launched from underwater could be controlled. They had launched a series of Sidewinders from a depth of 50 feet and photographed flight patterns as the missiles emerged from the water. Having clarified that aspect of the launch problem, the team next tackled the question of what effect noise and bubbles from the rocket motor would have on the submarine. When the station fired a Tiny Tim rocket from 100 feet under the sea, noise and pressure measurements showed that a submarine located three miles away could not detect the noise associated with an undersea firing. Furthermore, fish swimming near the rocket motor appeared not to be seriously affected by the blast. McLean concluded from these experiments that "the effects of underwater launching of rockets on submarines would, at least to a first order of magnitude, be very minor."

Another experiment demonstrated what appeared to be a safer, more satisfactory way of launching Polaris—bringing the missile from the submarine to the surface in a buoyant container, then starting a delayed launch. The first demonstration of this technique was with a scale-model container carrying a 2.75-inch rocket that was fired as the container broke through the surface of the water. Although the capsule concept was later abandoned as being too difficult to use on the surface, McLean credited these first launch experiments, paid for with E&F funds and undertaken through the initiative of station employees, with being "a major factor in reorienting the Navy's ballistic missile program from a surface-launched missile to a submarine-launched missile."[45]

These experiments reinforced Levering Smith's belief that he could rely on China Lakers for bright ideas to resolve technical difficulties associated with underwater launch. Smith also knew that the Pasadena Annex possessed experience in underwater ballistics unequaled elsewhere in the Navy or in private industry. In spring 1957 the station received an assignment from the Special Projects Office (then still part of BuOrd) to develop an underwater launching technique for the Polaris missile, to design and test the missile's launching vehicles, and to examine launcher and missile performance during launching.

Lockheed was the prime contractor for Polaris, but Smith had made up his mind that NOTS should provide the answers on launch depth, method of propelling the missile to the surface, safe underwater velocity for the missile as it reached the surface, maximum speed of the submarine, type of launch container, and effect of surface waves on an underwater launch.

The station had not just the expertise but also the physical assets necessary for this assignment. San Clemente Island's steep cliffs and clear offshore waters, extending 150 feet down to a white-sand ocean floor, offered ideal natural conditions for conducting and documenting the tests. The place was isolated enough to ensure safety and security, yet close enough to the resources of the Eleventh Naval District for fleet and logistical support from the mainland. The Polaris Pop-Up facility rapidly took shape on the east side of the island. Just to the south of the RAT missile launcher, two stout concrete launching pads were constructed on the ocean floor. A 114-foot pier was built at the launching site, and a crane installed for moving cargo. Seven clifftop spotting stations were equipped, and other range instrumentation was added, both above the ground and under water. Improvements also included 12 miles of new road. Some anonymous wag contributed a roadside sign, "You Are Now Entering San Clemente National Forest," that loomed incongruously above the windswept scrub brush.[46]

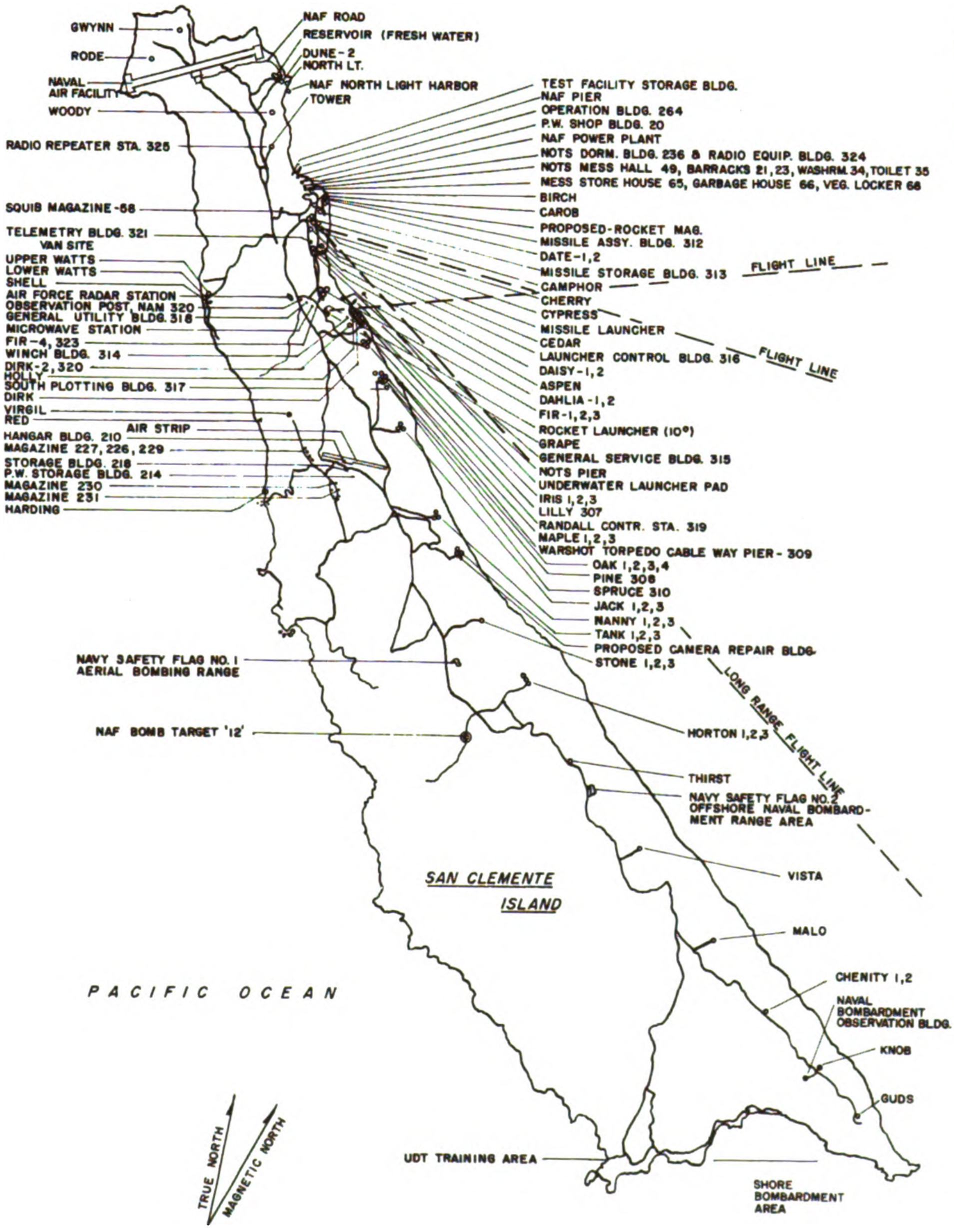
Work on Polaris also represented a challenge for the NOTS Fleet, which evolved as testing needs changed. A new incarnation of Trygon, the little fleet's first vessel, came into being in 1956 when the equipment from the old barge was installed in a new landing craft, utility (LCU) hull. For the first time Trygon

Trygon harbor utility craft (self-propelled) docked at Long Beach, 1958.

was assigned a hull number (YFU-44) and became an official naval vessel. The new, more seaworthy *Trygon* could move at almost twice the speed of the old one and thus could be positioned more efficiently for tests. A torpedo tube for launching experimental missiles could be mounted on an instrumented platform, which could then be lowered through a well in *Trygon*'s main deck. Fire-control information was transmitted to the surface by way of cables that reeled out as the platform moved down into the water.[47]

In December 1957 the Commandant Eleventh Naval District assigned the aging harbor-defense support ship *Butternut* (AN-9) to the NOTS Fleet, primarily to carry out towing operations between Long Beach and San Clemente Island. A veteran of net-laying and -tending operations in the New Hebrides and Solomon islands, Leyte Gulf, Guam, and Saipan, *Butternut* had just completed more than 10 years of continuous overseas deployment. Seven of her crew of 49 men and four officers were highly qualified divers. *Butternut* soon became indispensable for placing and tending the fallback net and assisting in missile recovery.[48] Other vessels included an instrumented YFN barge, an LCM diving barge, a catamaran staging vessel, and other small craft used as needed. Instrumentation on the island complemented that provided by the NOTS Fleet.[49]

Because of safety concerns, the first Pop-Up tests were not of missiles but of redwood logs, which NOTS engineers fired from an underwater launcher. Thorough camera coverage allowed the engineers to study every detail of hundreds of tests as the logs moved up from the depths, broke the surface, and



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San Clemente Island facilities, 1958.

The names (Grape, Cedar, Dalia, etc.) are for instrumentation sites.

Polaris launch off San Clemente Island, May 1958.

sailed up through the air to be caught by nets. As the tests progressed, concrete-filled steel cylinders replaced the logs, and the cylinder shapes became more Polaris-like. Finally, the actual missile structure was proof-tested. Pasadena people also used the Hydroballistics Laboratory at the Foothill Plant to study flow characteristics and other hydrodynamic properties demonstrated by Polaris models, each a third the size of the actual missile. This facility, comprising an open-jet vertical water tunnel and a 30-foot-high variable-atmosphere tank, was one of only three such ocean-atmosphere facilities in the world.[50]

Each Pop-Up test was a complicated affair, requiring a test crew of about 80 to prepare the missile and launcher for firing and bringing the NOTS Fleet out in force. Before crew members put to sea, they assembled and checked out test vehicles and missile prototypes at the Naval Ammunition and Net Depot, Seal Beach. After the crew loaded the test missile onto a buoyant launch vessel containing a simulated submarine launcher, a fleet tug towed the loaded launcher to its San Clemente Island test site. A winch on the island carefully lowered the launcher vessel, its buoyancy tanks flooding for stability, to the underwater pad.

The NOTS team then rigged two overlapping harbor-defense nets in the water above the launcher to catch the full-scale missile after launch. During preparation for launch, the team pulled apart the nets just enough for the missile to shoot up between them, then quickly clapped the nets back together to catch the missile upon its return to the water. A special crane, christened Fishhook, replaced the cumbersome net arrangement. Just as a fisherman would play out a powerful fish on a line, then reel in the fish as it tired, the Fishhook take-up mechanism reeled in a cable attached to the missile at the same speed as the missile's upward travel. At the instant of missile apogee, the cable reel stopped, causing the test "fish" to dangle in midair—another "big one" caught for later analysis.[51]

The station also contributed work in the propellant area that was important to the development not only of the sea-based deterrent but also of all of the nation's other rocket-propulsion-related programs. Research Department employees, principally Ed Price, who had earned an international reputation in the field of combustion instability, determined that the jet formed in voids or cracks in the propellant could lead to detonation. "A number of years later we had to come back to that with a much more extensive study," Levering Smith recalled, "but at that time we concluded that either X-ray or gamma ray . . . would be able to detect the size and length of cracks that could possibly lead to detonation. We then instituted an inspection system to reject propellant with such cracks." Dr. Jacob I. "Joe" Bujes, who had been the head of Salt Wells' radiographic unit until the plant closed in 1954, developed an inspection system that could tell whether a large propellant grain, such as that for Polaris, would be safe to carry and fire.[52]

With that propellant problem solved, the Weapons Development Department transferred all phases of the Pop-Up program to UOD, with the Test Division at Pasadena conducting the tests.[53] Just a month later, tests were going so well that the Pasadena Annex invited the press to witness a Polaris firing. "To the awed newsmen 'Operation Pop-Up' gave evidence of the feasibility of launching a devastating retaliatory weapon from a submerged atomic submarine," reported the *Rocketeer*. "To China Lake and Pasadena Naval Officers and civilian scientists and engineers the successful test was the crystallization of an idea based only on speculation, hope, and informal studies a year ago."[54] The Pop-Up tests would be completed on schedule in 1959.

Sidewinder to the Rescue

Even as NOTS worked on programs to meet new warfare needs, one station product that had recently joined the nation's arsenal proved its worth in September 1958 after Red China launched a massive artillery bombardment of Quemoy and Matsu. These two heavily fortified offshore islands had been held by Generalissimo Chiang Kai-shek's Republic of China ever since he had fled mainland China in 1949 and established his government-in-exile on the island of Formosa (now Taiwan). In an attempt to regain the offshore islands, the Chinese Communists fired 20,000 rounds of artillery on the first day of the onslaught alone.

The provocation was no surprise to Chiang and his American allies, who had been monitoring Mao Zedong's increasingly vitriolic radio threats for months. The Joint Chiefs agreed with the Eisenhower administration that defense of the offshore islands and of Nationalist China was vital to American security. If these two islands, and in turn the Nationalist stronghold of Formosa, were lost, the argument went, Japan, Thailand, or Vietnam might well be next. Eisenhower and his advisors concluded that the Chinese Reds needed a demonstration of American might to convince them that the United States would indeed come to the defense of its Nationalist ally.

The demonstration required careful planning, however, since Red China with the aid of its ally the Soviet Union had built up a formidable complex of military airfields and artillery emplacements that could devastate, not just the offshore islands, but the Nationalist stronghold in Formosa as well.

Adding further fuel to this potentially incendiary situation were the actions of Chiang himself who had ignored his American military advisors and spent months fortifying the Quemoy and Matsu garrisons. By summer 1958, fully a third of his total ground force of 300,000 men was stationed on the two offshore island groups.[55]

Although the Communists massed strong assets along the coast opposite Taiwan, they took for granted their own continued control of the skies over Formosa because their Soviet MiG-17s easily outperformed the aging F-86 Sabrejets of the Nationalist Chinese Air Force (CAF).[56]

As those responsible for defending Formosa cast about for a way to combat the MiGs, experienced U.S. pilots suggested that China Lake's Sidewinder missile could fill the bill. One advocate was Commander Glenn Tierney, former leader of Guided Missile Unit 61 and super salesman for Sidewinder, who had left NOTS in June 1957 for duty on the staff of Commander, Carrier Division Five, Pacific Fleet, on board *Ticonderoga* (CVA-14) in the South China Sea.

That 10 October—Ling Ling Day, the Chinese New Year—*Ticonderoga* was in Formosa Strait. Chiang Kai-shek came on board that day for a firepower demonstration in his honor, bringing with him a colonel in the U.S. Air Force. Tierney recalled being pulled aside by the colonel, who had heard great things about Sidewinder's capabilities.

"Would it be feasible to put Sidewinders on an F-86 and pick off some of these MiGs?" the colonel asked. "Absolutely. No question," Tierney replied.

Tierney had left China Lake before Sidewinder had actually "shot down anything quite in that category," but he'd seen enough to convince him that it could. Now he told the colonel with all the fervor of a born salesman, "We already have an F-86 at China Lake all rigged with the missiles, the launchers, the rails, the wiring, and the whole thing." Tierney urged the officer to contact Commander Selden N. "Sel" May, Tierney's successor as officer-in-charge of GMU-61, or Lieutenant Thomas S. Rogers, Jr., the unit's technical officer. "They'll tell you 'piece of cake,'" Tierney said.

That was the last he heard of the matter for almost a year.[57] But others were thinking the same thing. P. D. Stroop had become the chief of BuOrd in March 1958. That summer he received word from CNO Burke to direct China Lake help to Nationalist China. Stroop recalled that he was happy to do so. He had been following the progress of Sidewinder ever since his 1952–1953 assignment as NOTS' skipper. He also knew and appreciated the Nationalist Chinese, having just completed a 1957–1958 tour as Commander, Taiwan Patrol Force.[58]

One Saturday in July 1958 an urgent message arrived at NOTS, directing immediate participation in "Operation Black Magic," an effort to help the Nationalist CAF develop a Sidewinder capability on Korean-war-surplus F-86F aircraft. "I remember that weekend pretty well because I was command duty officer," said Moran, who was the assistant experimental officer. "The skipper and the deputy commander and the experimental officer, everybody was gone someplace, and so along about Friday evening we got a message from the Chief of Naval Operations talking about some interest in the Nationalist Chinese F-86s and Sidewinder."

Another message came, then another, both delivered very early that Saturday and both asking how soon NOTS could equip the Nationalists' F-86s with Sidewinders. Moran took action. His first problem was getting passports that weekend for the design and installation team. Moran called the Bureau of Naval Personnel in Washington and got the passports. He also dealt with McClellan Air Force Base to line up necessary parts for the F-86s. "We had that thing running at pretty goddamned good full velocity by Monday morning when the rest of the team came back," said Moran.[59]

All over the station, employees turned from their regular work to help meet the need. Metallurgist Warren Smith in the Analysis Branch of the Weapons Development Department recalled a visit from several workers from the Engineering Department's metallurgical lab. "Warren, we've got a problem to solve," they told him. "Nobody seems to know what to do about it. We thought we'd come over and ask if you could help us." They explained that NOTS needed to manufacture 95 Sidewinders as rapidly as they could be put together. The Engineering Department had gotten all the necessary materials together, but the steel canisters for the hot-gas generators had been annealed after manufacture, a mistake since the annealing made the steel so soft that the canisters couldn't be reliably crimped shut. Getting more manufactured would take weeks.

Smith, who had a long history of working with metals, recalled work he had done in 1943 in the research lab of a steel mill. Although the process he remembered was never used commercially, he reasoned that it would solve the problem with the Sidewinder canisters.

He wrote out a prescription for the heat-treating shop in Michelson Lab to heat the canisters to about 1,100 degrees Fahrenheit, quench them in water, then age them in either water or hot oil. The shop did the entire 94 canisters (minus one on which Smith had tried out the process) that same night. The canisters went the next morning to the China Lake Pilot Plant to be loaded with propellant, then were crimped shut and installed in the Sidewinders, which were immediately shipped out by air. Smith knew that the Sidewinders were needed in a hurry, but many years would pass before he learned the use of those particular missiles.[60]

Thanks to Smith and others like him, who needed to know only that an urgent call had come from the fleet, the station met its deadline. Within three weeks of that Saturday message, three military and three civilian China Lakers were on their way to Formosa, along with all the missiles and parts necessary to outfit the Nationalist F-86s with Sidewinder. Civilian members of the team were Lee Jagiello, Bob Sizemore, and Wayne Zellmer. Military participants included Sel May, Marine Gunnery Sergeant J. O. Thornton, and Navy aviation mechanic Joseph E. "Joe" Wojecki, leader of the Sidewinder flightline crew. In Formosa the team, augmented by Marine and Air Force enlisted personnel, reported to Commanding Officer, Air Base Advisory Team, Hsinchu Air Base

Wojecki remembered the visit as strenuous, with a schedule consisting of "work all day and then go to bed."[61] Once again China Lake ingenuity made do under less than ideal conditions. Upon delivery of enough equipment to modify 100 CAF F-86F aircraft, the group set to work on the first 20 modifications. At the same time, the China Lakers worked with the operations officer of Air Base Advisory Team to develop tactics and train the CAF pilots. By mid-September installation work was finished on all 20 aircraft, and an entire squadron (24 pilots) had completed training and was ready for combat.[62]

On 25 September the Office of Naval Intelligence received a situation report that in activities of the previous day, the MiGs of mainland China had been "very active," that they had been "aggressive, but ineffective" in three aerial encounters with the F-86 aircraft of the CAF. The most significant part of the message followed:

> Four (4) F-86F, Sidewinder equipped, engaged CHICOM MIG 17's. First employment of the system in combat. Six (6) weapons fired—four (4) kills.[63]

Mike Yi-Chan Chien (later a major in the CAF) was responsible for two of those four kills. "We saw four contrails in front of us," he remembered. "We approached the contrails. . . . . I saw the squadron commander pull up his nose, so I knew he was going to shoot. We were about 2 miles out at that point. . . . After he shoot one, I shoot one, and we saw that two MiGs exploded." Chien encountered two more MiGs and shot one of them down, "I was the first to land at the base. The major said, 'What happened to your Sidewinders?' I said, 'Well, I shot two, I got two.'" Another CAF pilot remembered the immediate aftermath. "Scared and discouraged, the enemy MiGs dispersed and scattered away in all directions. . . . All of our Sabres returned to base safely. We had won a glorious victory and opened a new era in utilizing air-to-air missiles in combat."[64]

A thrilled Tierney learned of the success from a high-priority message delivered the same day to the bridge of the *Ticonderoga*. "They did it!" he exclaimed proudly.[65]

Howie Wilcox later emphasized the larger significance of the incident. "I felt that this was an ideal application of the Sidewinder missile, to suppress what had promised to become a shooting war because it made it clear to the other side that they were not going to be able to dominate the air," he said. "In fact, they were not even going to be able to *compete* in the air."[66]

By demonstrating that the MiG was no longer invulnerable, Sidewinder's first use in combat had helped cool a tense situation in Formosa Strait. No less an authority than President Eisenhower noted that "the crisis was really eased by the success of the Nationalist Navy, with the help of United States advisers, in defeating the Red interdiction of Quemoy. . . . In the aerial battles the Chinese Nationalists' fighter planes, some equipped with Sidewinder air-to-air missiles, took a heavy, one-sided toll against the Communist Air Force."[67]

The immediate Chinese reaction to the Sidewinder attack and to a related rearming of Formosa was to issue a warning that these incidents had worsened the crisis. Events of the next few days and weeks, however, showed that the opposite was the case. On 6 October 1958, Red China announced a weeklong unilateral cease-fire. After another week, the bombardment resumed, but on 25 October the Communists announced that they would bombard the island only on alternate days; this peculiar policy (resulting in what Eisenhower termed a "Gilbert and Sullivan war") continued into the early 1960s. Clearly, the crisis had passed. The Sidewinder triumph had conclusively demonstrated that China's MiG-17s could no longer rule the skies. As Stroop observed, Sidewinder's effectiveness "scared the hell out of the Chinese on the mainland."[68]

The missile's combat debut aroused worldwide interest. *Aviation Week* reported on 6 October that Sidewinder's use in the Formosa crisis "marked the first time U.S. air-to-air missiles have been put to test in actual combat." Furthermore, the magazine reported, NATO members with F-86s in their inventories were "being supplied with kits to modify their aircraft to accommodate the Sidewinder." The Associated Press reported similarly, "More than a dozen allied and friendly countries either have the pencil-shaped missiles or are pressing to get them."[69]

"As far as I'm concerned, everybody who ever worked at China Lake, all the money it took to pay them, was paid off right there with that one incident," said John Boyle.[70] With that demonstration, the Sidewinder episode over Formosa Strait serves as a fitting climax to an extraordinary decade of NOTS creativity and productivity.

19

Lessons From the Magnificent Mavericks

The bright, highly motivated individuals populating this book contributed colorful personalities and a legendary work ethic to a decade of accomplishment at the Naval Ordnance Test Station. As military and civilian employees worked together to meet the nation's ordnance needs, they developed an unusual approach to their tasks—and their lives—that resulted in high morale and extraordinary productivity.

The station was not of course a utopia, but a gritty, down-to-earth place where people argued, where red tape sometimes foiled best-laid plans, where promising projects sometimes failed or were canceled, where conflicting demands and scarce resources delayed schedules, where requirements sometimes made no sense to the people who had to meet them, even where stinging desert winds and inadequate housing could drive away all but the hardiest workers and their families. Nevertheless, some powerfully positive conditions led to a workplace environment that the magnificent mavericks of NOTS generally remember as the closest thing to utopia encountered in their accomplished careers.

Teamwork Based on Principles of Operation

The Naval Ordnance Test Station of the post-World War II period was a creature of its founders, a living organism that derived vitality from deeply felt principles of operation. "It is our opinion that the proper binding of service and laboratory experience in the technical staff . . . will produce results in weapons development superior to those of either all-civilian or all-military operation," said Dr. L.T.E. Thompson. That philosophy was the station's bedrock.[1]

Work at NOTS encompassed all aspects of the RDT&E process, with a continuous regeneration of ideas and information flowing through the organization, a synergy of immense value to the quality of the end product. "While the project engineer is a central authority and information source specializing in the particular rocket and the system components with which it will be used, he obviously cannot be an expert in all the specialties which should be brought to bear," said Emory Ellis. "However, he calls freely for assistance from specialists in ballistics, explosives, propellants, metallurgy, production engineering, test engineering and others." The scientists in the labs, the propellant and explosive makers at the pilot plants, the machinists and apprentices in the shops, the test schedulers and instrumentation experts on the ranges, the military units on the ground, the pilots in the sky—all contributed ideas and energy not only to their own tasks but also to other station projects, even those outside their perceived areas of expertise.[2] Because the NOTS way of work depended on informal, cross-organizational relationships, the motivational and communication problems connected with "stovepipe" management were largely missing.

Military and civilian leaders relied on powerful advocates in Washington to support both the principles upon which NOTS was founded and the projects on which the station worked. Of particular note was the insistence on giving the civilian scientists and engineers authority over the technical work while maintaining strong advisory roles for the experimental officer's staff and the military personnel assigned to the Naval Air Facility and tenant commands. As Experimental Officer Tom Connolly commented, "The philosophy by which NOTS is guided welcomes and thrives on the stimulating influence that the problems and ideas of fleet operating units provide."[3]

The invention and fleet introduction of Sidewinder, a story that weaves its golden thread through the decade covered by this book, is a prime example of that philosophy at work. The NOTS experimental officer and his group operated "in much the same manner as the merchandising and market analysis groups in a large commercial organization" to provide the "additional feedback loop connecting the designer with the people actually using the equipment," said Dr. Bill McLean. "We believe that the close personal contacts operating throughout a design program are capable of much more effective and rapid action than can be accomplished by means of written specifications or other types of requirements."[4]

A dramatic improvement in communication between the civilian creators and the military users occurred during the Korean conflict. The NOTS Fleet Support Office, established in December 1952, formalized a policy of direct communication with fleet personnel as they used China Lake and Pasadena products. The station discovered the benefits of sending smart technical people to the front to observe how their products worked under the rigors of combat, to listen to what the fleet operators needed, then to return home to develop and test solutions. Shrike, Mighty Mouse, and many other NOTS products owed their existence to the binding of service and laboratory experience that began when the station was founded and that became even stronger during the early years of the guided-missile era.

"I must say I never have understood the system for selecting naval officers to be sent here," said Hack Wilson. "But whatever it is, it certainly works well most of the time. For the sake of the future, we can only hope that those who make the military assignments to NWC will understand the peculiar nature of Navy laboratories."[5] Most of the commanders assigned to NOTS during the 1948–1958 era understood their roles well and played them superbly, focusing on strengthening the resources the technical employees needed to do their jobs. Also critical to the station's smooth functioning was a corresponding understanding on the part of civilian leaders. Without the respect and communication necessary to keep the entire team functioning, NOTS could lose effectiveness, a lesson several station leaders learned the hard way.

Freedom for Individual Initiative

"You should have good, strong people in a position and then give them the authority . . . to carry out the work that they are assigned to do," said range pioneer Duane Mack. "But if you go through a process of getting approval after approval after approval, pretty soon you don't give a damn whether it's ever done, even though you know it should be done."[6] NOTS technical people enjoyed unusual authority to come up with ideas, then to pursue them in an atmosphere relatively free of paperwork and bureaucratic delays. The relative simplicity of Bureau of Ordnance reporting requirements also helped keep morale high and frustration minimal. As McLean emphasized, the ability to test the feasibility of an idea rather than working from an externally devised specification was central to the station's productivity. Furthermore, members of the administrative staff at NOTS kept much of the paperwork burden for themselves; they understood the importance of the innovations they were supporting and shared the prevailing can-do attitude and sense of ownership.

Trust in the individual resulted in tolerance of creative work schedules and of personal idiosyncrasies. In other words, the NOTS mavericks had wide leeway to be mavericks. Emblematic of that trust was Newt Ward's all-encompassing list of employees who could purchase materials from shop stores. To a remarkable extent, employees showed that they merited that trust.

"We must have new ideas if we are not to go to seed," said Thompson.[7] He and other NOTS leaders encouraged employees to take early responsibility for projects, so that junior professionals worked side by side with world-renowned technical experts. An engineer, a scientist, a technician, an administrator, or a pilot with a good idea had wide latitude to go wherever the idea could be best developed, both inside and outside his immediate organization.

The physicists, chemists, mathematicians, and ballisticians of the Research Department were an important source of ideas. "You just have to do research before you know what you want," said McLean, pointing out that "research leads to requirements. It does not follow from requirements."[8] Indeed, all three NOTS technical directors during 1948–1958 supported a vigorous research program, which they saw as essential to recruitment success as well as to a robust technical program. Although some of the projects on the frontiers of science did not appear to have practical applications, the emphasis was on research destined to improve the physics or the chemistry of products in the fleet. Significant applications resulted, notably dramatically improved energetic materials.

For the creative process to yield something of value, station leaders believed scientists and engineers had to have the freedom to try risky concepts with the understanding that they could be abandoned if they didn't work. The OMAR project is one illustration of that approach. When the station returned unexpended OMAR funds to Washington, explaining that the project relied on concepts not yet mature enough to work, some Bureau of Ordnance officials were aghast that NOTS leaders would so freely abandon a project they had struggled to fund. Fortunately, the bureau chief supported the action as a fiscally responsible one.

McLean was also willing to let others try ideas in which they passionately believed, even when he doubted their success, a philosophy well illustrated by the Walleye development. "How do you get an idea? I haven't the foggiest notion," said McLean. "You start working on something interesting and as you go along you keep getting ideas that change it."[9] He planted ideas everywhere and accepted them from anywhere, a practice disconcerting to those who preferred an orderly organization with well-defined lines of authority and responsibility. The development process McLean preferred was messy and sometimes inefficient, but it was also likely to result in the creative solutions that come when several fine minds think about the same problem. "He'd start the same fire in five different places in order to get a competitive thing going, because he recognized that people pay off under competitive situations," said Howie Wilcox.[10]

McLean saw an insistence on careful coordination of work as one of nine backward steps that could rapidly turn a creative organization into one doing only routine work. Other creativity killers he fought were close adherence to regulations, concentration on planning and scheduling, rigorous adherence to defined working hours, insistence on multiple reviews before work could begin, suboptimization to ensure perfect components, centralization of as many functions as possible, insistence on avoiding mistakes, and insistence on a successful organization, an emphasis that he said would decrease the need for change and justify the opposition to it.[11]

The NOTS approach to technical challenges angered some in Washington, notably missile czar K. T. Keller, who believed weapon development should follow the model of the industrial mass-production line. But as McLean championed freedom from bureaucratic constraints, he had the support of the powerful civilian leaders on the NOTS Advisory Board, of most of NOTS' commanders, and of many of the Navy's highest officers. His philosophy may have seemed heretical to some, but it demonstrably worked at NOTS.

Pragmatism and Emphasis on Design Simplicity

Along with the support of risky ideas, however, went a healthy dose of pragmatism. Even though McLean pursued numerous projects that did not fit within the station's defined mission, he and the NOTS Research Board focused on applications they believed the Navy needed. They also stressed keeping weapons and systems as simple and inexpensive as possible. "Bill McLean established the principle that it's much harder to do it simply, but if you do, it will be much better in the end," Don Friedman said. "Whereas if you take the more complex, easier road, you're going to be mired in difficulty down the road."[12]

That design philosophy meant a preference for using existing technology rather than trying something whose maturity hadn't yet been proved. Existing technology meant elegant new applications of proven concepts; it did not mean cobbling together off-the-shelf components, a practice McLean believed would almost inevitably result in compromises and complications. "I become exceedingly skeptical whenever I hear the phrase that 'a missile is to be composed entirely of off-the-shelf items,'" he said. "I feel this design will probably have the same structural strength and beauty of conception that would be represented by a montage of photographs for the production of a mural painting. It may result in a masterpiece, but the probability is not high."[13]

Inevitably, design trade-offs were needed. "One of the things you have to remember when you get to a mountain is that you don't try to go through it. You go around it," McLean would advise the technical worker confronting a knotty problem.[14] The elegantly simple Sidewinder rolleron was one such mountain-avoiding solution. The station's pragmatists also found innovative ways to meet demanding schedules and seemingly impossible technical challenges by adapting the materials and people at hand. A legendary example was the Ram rocket, where the corridor of Michelson Lab became a nighttime assembly line where all available hands, from secretaries to department heads, built fuzes incorporating the springs from wooden clothespins.

The station's emphasis on simple, practical components paid off when a system entered the manufacturing phase. With the release to production of each new weapon system, the NOTS technical staff learned more about the value of making engineering changes before the production phase and of communicating clearly with the manufacturer. In several cases, NOTS employees became troubleshooters for weapons and components developed elsewhere, a type of work that would become increasing important in the 1960s and '70s. Even more to the point, an increasing emphasis on communication in the combat environment resulted in simplified assembly methods and training materials for the end user.

Flexible Funding

Early station leaders had wide funding latitude because of the postwar Caltech monies Levering Smith was able to provide. An informal "tax" on project funds bridged the gap between that early discretionary funding and the BuOrd foundational research fund, which began in late 1949. Exploratory and foundational (E&F) money—funds controlled by NOTS leaders and not designated for specific projects or functions—allowed employees to pursue ideas as yet too fragile to survive in the highly political competition for funds that almost inevitably occurred as a system matured.

Both Thompson and McLean saw discretionary funding as cost-effective, as well as important to recruitment and morale. "If the laboratories are given authority to carry a large number of perhaps 'wild' schemes through to the demonstration of feasibility, or lack of it, we can generate information which will allow more accurate prediction of production costs and production feasibility," said McLean.[15] Station leaders also valued the rapid progress possible when the bureaucratic roadblocks associated with the funding process were removed.

Also notable in the funding area were the creative routes taken to keep the necessary monies flowing to fledgling projects. In Sidewinder's case, for example, the missile was called first a rocket, then a fuze project, then a feasibility study on its way to success as the world's first infrared-guided air-to-air missile. Such unconventional solutions helped establish NOTS' reputation as a maverick organization, but during the decade 1948–1958, powerful station supporters in Washington, notably Deak Parsons, generally had full knowledge of and participation in these solutions.

Umbrella of Protection

The history of NOTS contains numerous examples of how its leaders sought and received invaluable support and protection from higher up. "The Caltech Mafia that started the place, the Thompsons and the Lauritsens, and the like, all respected Bill [McLean], and the Navy people, like P. D. Stroop and others who went on to high positions in the Navy, all provided an umbrella of protection for Bill," said Walt LaBerge. "This umbrella allowed him to do things that as the alumni became less powerful, subsequent TDs [technical directors] were not able to do because they didn't have the protection Bill had as a result of the early acquaintances he had made and the situation at the end of the war, when the very good people from Caltech and the Navy were stationed here."[16]

McLean also inherited powerful allies from Thompson, whose umbrella of support included Parsons, Bureau Chief Noble, and other members of the Washington power elite. The significance of these relationships was well described to China Lake employees in 1949 by Dr. Lawrence R. Hafstad, a member of the nation's scientific elite who sat on the first NOTS Advisory Board. "It happens that your Director Thompson here was at Dahlgren throughout the period when most of the men now in responsible positions were serving their tour of duty at Dahlgren, and I think it has proved to be both valuable and comforting that the Navy officers in charge of the programs know Thompson so well and have so much confidence in his abilities and in his decisions," he told the China Lakers. "This is the sort of thing that you need in research. A good man in whom the top people have lots of confidence."[17]

Military tours at NOTS also frequently led to support for the station and its work. A prominent example was Levering Smith, whose trust in NOTS technical expertise paid off when the Navy needed to rethink its fleet ballistic missile program. Because Smith knew the caliber of the station's technical staff, he relied on NOTS for the innovative thinking that resulted in a more practical, streamlined design for the Polaris missile, as well as a revolutionary change in the national policy of nuclear deterrence. Throughout his distinguished naval career, he sent work to China Lake and supported that work with the necessary funding. As technical director of the Polaris Missile

Program, he also sponsored underwater-launch test facilities at San Clemente Island and the Skytop propulsion-test stand, the nation's largest static test facility, at China Lake.

A significant part of the sheltering umbrella came from alumni of the California Institute of Technology who had worked at NOTS during its early years or who had first encountered station employees when they were fellow students of Dr. Charles C. Lauritsen and other superb scientists on the Caltech faculty. In one example of the Caltech connection at work, McLean was able to turn to Assistant Secretary of the Air Force Trevor Gardner for help in convincing the Air Force to arm its aircraft with Sidewinder.

A formal mechanism for the umbrella of support began in 1949, when Noble established the NOTS Advisory Board at Thompson's request. Most of the board's initial members had worked in the World War II scientific establishment, and they knew the importance of a place like NOTS to the nation's defense. Furthermore, when Thompson wanted an influential leader for the board, Charlie Lauritsen stepped up to the plate. Lauritsen, who had located the ground upon which China Lake stood, is an excellent example of the sustained support NOTS could rely on over an entire career. Another example is Thompson himself, who continued to speak out on the station's behalf when he moved on to other influential positions and even after he retired.

Access to Necessary Skills and Resources

When Hack Wilson looked back at the end of his career to muse on NOTS' success, he described the core of that success as "the value of getting the proper mix of people together in a creative environment with the proper resources."[18] Station employees had access to all the tools and facilities they needed to accomplish their work. Laboratories, air and ground ranges, a sea range, instrumented test sites, pilot plants, and machine shops supported the spectrum of work from research through prototype production. During the decade of 1948–1958, computers and other sophisticated tools took their place beside handmade, yet effective assets such as the "Gooney-bird" camera stations made from modified machine-gun mounts. New laboratories and test facilities rose on the desert—some to fill testing needs still experienced today, some to be modified after early requirements evaporated.

The station's weapon developers knew their products needed to be tested under conditions as close as possible to those encountered in combat. China Lake's varied terrain and sophisticated instrumentation made these conditions possible in the 1950s and today. The ranges were also valuable because of their proximity to research and development activities. "We just walk out from the laboratory and put our product in the air here," said Ashworth. "I think that's a major strength of this laboratory."[19]

To keep the proper mix of creative people, both the commander and the technical director found much of their time taken up by the mundane but essential matter of housing to attract and keep employees and their families on the desert. Until housing and other facility needs could be met, some desirable work had to be turned away. Several groups assigned to NOTS, notably VX-5, had to wait for the necessary facilities. The arrival of VX-5 before a much-needed new hangar could be built, however, is an example of the pragmatism with which the station dealt with less-than-desirable conditions. The NOTS pioneers took pride in a way of life that involved living in single rooms and tiny trailers, sharing desks, using dart-shaped pieces of plywood to take the place of expensive aerial targets, and otherwise making do.

That creative pragmatism extended to recruitment too. When the station couldn't attract outside talent, it trained its own specialists, turning housewives into draftsmen, encouraging employees to move freely between work groups to develop new skills, and creating skilled technicians through its apprentice program. These programs and an inclusive, challenging work environment led to well-trained machinists, construction workers, range personnel, and other specialists in a variety of trades with a shared feeling of ownership and a shared goal of surmounting all obstacles to solve the technical problems at hand.

Concern for the Big Picture

China Lakers didn't wait for requirements from Washington, but studied the emerging needs of the fleet, then devised solutions to those needs. That meant that news of NOTS projects often flowed to Washington via informal channels, then became official requirements flowing back to NOTS.

The station was one of the first of the Navy laboratories to establish a central evaluation and planning group, the ancestor of today's Weapons Planning Group. The Research Board used information from this knowledgeable in-house source, from the experimental officer's staff, and from an excellent network in the scientific establishment to study and debate what the station's next projects should be. Sometimes the board's conclusions did not match those of other weapons planners. Perhaps the most notable divergence came in the mid-1950s when the defense establishment sought nuclear applications for virtually every weapon while McLean, Ashworth, and the mavericks on the desert insisted on a robust conventional-weapon program. Events of the emerging era of limited and unconventional warfare soon proved the wisdom of NOTS' course.

Station leaders stressed the importance of looking ahead and authorized numerous projects pushing the envelope of the possible. "Don't build a new missile with almost obsolescent components," Frank Knemeyer emphasized.[20] That forward-looking approach depended on a full-spectrum laboratory employing people with high morale, dedication to their jobs, and the technical expertise to make confident, competent predications that could be turned into workable products.

Can-Do Spirit

An essential ingredient in NOTS' success was the buoyant spirit that accompanied a clear sense of goals and that prevailed from top to bottom in the youthful organization. "There was just a lot of confident optimism," said Frank Cartwright. "Happily, between confident and optimism there's also the word competent. So there was one hell of a lot of competent confidence."[21] That confidence led journeyman mechanic Chris S. Hinzo, who helped solve a power-supply problem during Sidewinder assembly, to rejoice, "I'm proud to say I did it, with God's help, after saying, 'I can do it!'"[22]

For Hinzo, for Warren Smith who worked long hours to hand-build the Sidewinders used in Formosa Strait, for Don Moore who began his career helping build "dry suits" in McLean's garage, for Don Stewart who created a nutation damper by applying a lesson he learned from the family washing machine, and for many, many others, a confident approach to the technical challenge almost invariably led to accomplishment.

Sense of Community

The isolation of the Indian Wells Valley set up different challenges at China Lake from those at the Pasadena Annex, where a ready-made community existed. But that very isolation became an asset in the creative hands of the China Lakers. "The motivation and productivity of all employees were enhanced when we all lived on base," said John Di Pol. "There was a great sense of community." Employees, who lived mere minutes from their jobs, frequently returned to their engrossing work after hours. Work and home were a seamless fabric, and the goal-driven employees often solved technical problems in their garages, over the back fence, or over a party punchbowl. Leroy Doig III remembered swimming at the Officers Club pool while his dad and China Lake colleagues scribbled poolside equations on scrap paper. "If we had a turf squabble on the job with someone who also was our neighbor, we often settled it over the fence on a Saturday morning," Di Pol added.[23]

Although strong-minded, capable women—systems administrator Lillian Regelson, physicist Marguerite Rogers, weapons analyst Pauline Rolf, and others—contributed from the start to the technical work, a more typical scenario of the early years saw wives working together to make a community with superb schools, clubs and social services, culture, and recreation while their husbands spent long hours in laboratories and on ranges. Some marriages didn't survive the frontier living conditions and the husbands' obsession with their work, but many marriages grew stronger as the wives accepted the challenge implicit in the phrase, "We're all in this together."

"We were all very intense in those days," said John Boyle, citing projects where "you worked a couple of days straight if you had to do something."[24] The wives helped make possible day-and-night work on projects like the Ram antitank rocket. During that project, Ditty Riggs recalled, "Leroy was crunching numbers with Ed Winkel and Albin Fojt. They were only getting about four hours sleep a night for the 28 days it took to produce Ram. After two days of odd hours and odd 'feeding' times, I called Janet Winkel and Lil Fojt and we set up a feeding schedule." Each of the wives would provide one meal a day for the three husbands. "By changing duties for each day, we got this worked down to a pretty good science and provided the three men with their schedules as to where they were to go when. It worked out great, and gave us three women time to chase the kids."[25] The wives' uncomplaining support and the help available via the locally famed phone number, 7177, which brought Public Works repair men to the door, allowed the husbands to focus on their jobs without worry about how things were going at home.

Wives also directly supported their husbands' work by entertaining official visitors. Of particular note was LaV McLean's open-handed hospitality to everyone from the newest junior professional to the Chief of Naval Operations. "She treated everybody the same, knew everybody's name, loved individual people, asked about the kids, used their names, and never appeared to think about herself, but to genuinely be interested about your situation," said Walt LaBerge. "And she applied that attitude to at least a thousand different families over the course of the time that I was on the base."[26]

The sunshine of her smile warmed the hearts of powerful visitors too and led to the helpful relationships that P. D. Stroop had in mind when he called her "Bill's public-relations man."[27] Countless parties celebrated milestones, both successes and failures.

The wives often knew nothing about the technical accomplishments being celebrated, but they shared the knowledge that the work was important and that they were contributing to China Lake's success.

Pride in Contributions

The pragmatism and support for individual initiative demonstrated at the Naval Ordnance Test Station of 1948–1958 offer powerful lessons for organizations seeking to bring intellectual products to reality. China Lake and its Pasadena Annex worked across the spectrum from basic and applied research to development to testing to pilot production to fleet introduction and support to life-cycle production support, turning out extraordinary innovations that still influence national defense today.

Employees generally worked long hours for relatively low pay—but they considered themselves wealthy in more significant ways. "Nowhere could one become as rich in pride and satisfaction in a contribution to society," said Knemeyer. "During the various conflicts from Korea, Vietnam, to present, there is nothing that can make you feel so rich as when combatants tell you how your system saved their lives and helped them to accomplish their missions."[28]

"The people made NOTS," said Bud Sewell. "The leaders were inspiring, the co-workers were amazing . . . they were all dedicated to technical excellence. To me, NOTS was a state of mind."[29]

Glossary

11ND Eleventh Naval District.

A head Alternate seeker head proposed for Sidewinder missile; the A head used a rotating mirror supported on a spherical bearing.

AAUW American Association of University Women.

Administrative Board NOTS management group responsible for recommending matters of administrative policy.

AEC Atomic Energy Commission.

AERO 6A Inexpensive seven-round rocket launching pod for 2.75-inch Mighty Mouse rocket.

AFCS Aircraft fire-control system.

AIM-9B Early, highly successful version of Sidewinder.

AN/ASB A radar-optical bomb director.

AN/DAN-3 Seeker system developed by Aerojet Engineering Company for BuAer; intended for Sparrow missile.

AO&T Aviation Ordnance and Test Department.

AOD Aviation Ordnance Department.

APL Applied Physics Laboratory, Johns Hopkins University.

Area R Explosives research and development test range in the China Lake complex.

Army Air Forces Army precursor to the Air Force, which was established by the National Security Act of 1947. The Army Air Corps, established in 1926, became a subordinate branch of the Army Air Forces, established in 1941.

ARPA Advanced Research Projects Agency.

ASD(AE) Assistant secretary of defense for applications engineering, established in 1953.

ASD(R&D) Assistant secretary of defense for research and development, established in 1953.

Askania cinetheodolite Photographic tracking instrument that records on each film frame azimuth and elevation angles of the optical axis of the instrument.

ASROC Antisubmarine Rocket.

ATAR 6.5-Inch Antitank Aircraft Rocket, a rocket with a shaped-charge warhead, also called Ram and used during the Korean War.

AVOSET Automatic Video System of Edge Tracking, electronic tracking system developed by NOL Corona.

B head Alternate seeker head proposed for Sidewinder missile; the B head used conventional gimbal supports for the gyro and a nonrotating Cassegrainian telescope mirror.

B-1 Range Fixed-target air-to-ground range in the China Lake complex.

B-4 Range Moving-target range incorporating a 2.76-mile-long standard-gauge two-rail track.

Ballistic missile A missile which, after guidance during launch and takeoff, travels unpowered in a ballistic trajectory.

Bat Radar-guided bomb made of plywood, the first fully automatic guided weapon used successfully in combat (in the Pacific during the final months of World War II).

BOAR 30.5-inch Bombardment Aircraft Rocket, one of the first rockets designed to carry a nuclear warhead.

BOCA Bureau of Ordnance Committee on Aeroballistics.

BOQ Bachelor Officers Quarters.

BOTLO Bureau of Ordnance Technical Liaison Office.

Big Stoop Two-stage experimental weapon designed to test whether a solid-fuel surface-launched rocket could deliver a nuclear warhead.

BTV Burner Test Vehicle for Terrier tests.

BuAer Bureau of Aeronautics.

Buda car Railway car made by the Buda Foundry and Manufacturing Company and designed to run independently down the track; used as a test vehicle in early track tests.

BuDocks Bureau of Yards and Docks.

Bumblebee Surface-launched ramjet missile whose development began during World War II to counter the kamikaze threat in the Pacific.

BuOrd Bureau of Ordnance.

BuShips Bureau of Ships.

BuWeps Bureau of Naval Weapons.

C head Alternate seeker head proposed for Sidewinder missile; the C head used a rotating motor and an internal bearing for the gimbal system.

C Range Air-to-ground range in the China Lake complex; also called Charlie Range.

CAA Civil Aeronautics Authority.

CAF Nationalist Chinese Air Force.

Caltech California Institute of Technology.

Canard Horizontal fin or control surface forward of the main lifting surface in an aerodynamic vehicle.

Cassegrainian telescope Reflecting telescope in which a small hyperboloidal mirror reflects the convergent beam from the paraboloidal primary mirror through a hole in the primary mirror to an eyepiece in back of the primary mirror.

CHICOM Chinese Communist.

CLPP China Lake Pilot Plant.

Composition B A castable explosive.

CVA Navy designation for attack carrier.

CVAC Consolidated Vultee Aircraft Corporation, later Convair Division of General Dynamics Corporation.

D head One of the series of Sidewinder alternate warheads; used on the OMAR optical beam-riding rocket.

D&P Design and Production Department, headquartered in Pasadena.

DDR&E Director of defense research and engineering.

Detent Catch or lever that locks the movement of one part of a mechanism.

DoD Department of Defense, established in 1949.

Dove General-purpose 1,000-pound guided bomb incorporating infrared homing.

E head Alternate seeker head proposed by the Eastman Kodak Company for the Sidewinder missile.

E&F Exploratory and foundational funding, discretionary funding used for basic and applied research programs.

Eberstadt Task Force Subcommittee of the Hoover Commission; issued a November 1948 report recommending civilian control of the military establishment.

EDO Engineering duty officer (ordnance).

Ejecta Material violently thrown out during an explosion.

Elsie Armor-piercing bomb with a nuclear warhead; intended for subsurface detonation against armored ship decks, underground bunkers, and reinforced submarine pens.

ENIAC Electronic Numerical Integrator and Calculator, a pioneering analog computer that began operation at University of Pennsylvania in 1946.

EWA Employees Welfare Association, precursor to the China Lake Community Council.

EX-2 Experimental torpedo design using electric propulsion; used for Mk 44 torpedo.

EX-5 Redesigned version of Mk 43 air-launched antisubmarine torpedo, featuring a protective air-brake clamshell to be jettisoned on water entry.

EX-8 Torpedo powered by a hot-gas engine and propelled by a pumpjet; became the Mk 46 torpedo.

EX-16 Fire-control system incorporating advances in computing technology.

Fat Man Mk III atom bomb, implosion type.

FFAR Folding-Fin Aircraft Rocket.

FHA Federal Housing Administration.

First Terrier SAM Battalion First Terrier Surface-to-Air Missile Battalion, previously First Provisional Marine Guided Missile Battalion; established at NOTS in 1955 and reassigned to Twentynine Palms the following year.

Foldwinder Sidewinder 1B; an attempt to incorporate folding fins into the missile's design.

Foundational Research Fund Monies funding research at the discretion of the technical director of a Navy laboratory; BuOrd established the fund in 1950.

FS 567 Feasibility Study 567, a designation for Sidewinder in 1951.

FS 602 Feasibility Study 602, a designation for the Optically Maneuvered Aircraft Rocket (OMAR) in 1951.

G-1 Range 37-mile-long live-firing range in the China Lake complex; used for all exterior ballistic rocket tests involving high-explosive heads.

G-2 Range Pie-shaped firing range beginning on the China Lake playa and extending parallel to G-1 Range for 10 miles.

G-4 Range Exterior-ballistics range overlooking Coso Dry Lake and containing a 3,000-foot-long track.

Gardner Committee Group established by DoD in 1953 under the leadership of Air Force Special Assistant for Research and Development Trevor Gardner; charged with making a comparative analysis of all guided-missile programs, with the objective of eliminating unnecessary duplication.

Gas generator Burning propellant driving a turbo alternator to provide a missile's power.

GASR 5.0-inch air-to-air spin-stabilized rocket.

GEDA Goodyear Aircraft Corporation Electronic Differential Analyzer; used to transfer flight data to punched cards.

G-Gimlet Name for the original version of the 2.0-inch Gimlet rocket; see T-Gimlet.

Gimlet 2.0-Inch Folding-Fin Rocket.

GMC Committee on Guided Missiles, set up by the DoD Research and Development Board in late 1947.

GMU-25 Guided Missile Unit 25, the former Terrier section of GMU-61, redesignated in 1955 to receive training in operation and maintenance of the Terrier missile.

GMU-61 Guided Missile Unit 61, established in 1952 and sent to China Lake in 1953 to receive specialized training in the operation and maintenance of Sidewinder, OMAR, and Terrier missiles.

GT&R General Tire and Rubber Company, which ran NOTS Pasadena Annex under contract to the Navy in 1945–1948.

Guided missile A projectile whose course may be altered during flight (such as by radiation from the target).

Gun Club Elite cadre of promising naval officers assigned to the Naval Proving Ground, Dahlgren, for ordnance postgraduate training.

H-9 Relatively cool, slow-burning propellant developed by Allegheny Ballistics Laboratory.

Harnwell Report Post-World War II torpedo study directed by BuOrd to make recommendations on countermeasures, standardization, targets, evaluation, and field testing, as well as on a reorganization of the Navy's torpedo RDT&E program.

HEAT High-Explosive Antitank Warhead, Mk 32, designed for Zuni rocket.

Heat homing rocket Original name of the Sidewinder missile as proposed by Dr. William B. McLean in 1949.

Holy Moses Nickname for 5.0-Inch High-Velocity Aircraft Rocket.

HPAA 5.0-Inch High-Performance Air-to-Air Rocket, a folding-fin variant of the High-Performance Air-to-Ground Rocket.

HPAG 5.0-Inch High-Performance Air-to-Ground Rocket.

HPAW 5.0-Inch High-Performance Air-to-Water Rocket.

HVAR 5.0-Inch High-Velocity Aircraft Rocket nicknamed Holy Moses.

Hydra One name for the Demolition Line Charge, developed by NOTS in 1951.

Hypergolic Igniting upon contact of the components (self-igniting).

IBM 701 Defense Calculator International Business Machines' first production computer and NOTS' first mainframe computer. The station accepted delivery in 1953 of the eighth of only 19 ever built.

ICBM Intercontinental Ballistic Missile.

IPAR Improved Performance Aircraft Rocket.

IPFF Improved Performance Folding-Fin Rocket.

IR Infrared radiation.

IR&IED funds Independent research and independent exploratory development discretionary funds; the IED category emerged in 1959, and foundational research funds were renamed IR funds in 1964.

IRAH Infrared Alternate Head for Sidewinder; also known as Sidewinder 1D.

IRBM Intermediate-Range Ballistic Missile.

IRIG Inter-Range Instrumentation Group, established in 1952.

JATO Jet-assisted takeoff.

JCS Joint Chiefs of Staff.

JP Junior professional, a recently graduated scientist or engineer assigned to a first-year training program. Now called Engineering and Scientist Development Program (ESDP).

JPL Jet Propulsion Laboratory.

JPN Double-base external-burning propellant; the principal solid propellant in U.S. rockets during World War II.

JRB Small twin-engined transport aircraft.

JRDB Joint Research and Development Board, established by the secretaries of War and the Navy in 1946 to coordinate R&D activities of the military services.

JS-3 Massive 57-ton Soviet tanks used in the Korean War; named for Joseph Stalin.

Jupiter C Army ballistic missile consisting of a Redstone with clusters of small rockets for the upper stages and designed to loft a satellite into orbit.

Jupiter S Joint Army-Navy program to develop a sea-based fleet ballistic missile using Jupiter technology.

K-2 Range Terminal ballistics range with a 1,500-foot two-rail track.

K-3 Range Crosswind Firing Range, site of a 1,500-foot single-rail subsonic track.

Kellerizing Approach OSD Director of Guided Missiles K. T. Keller took to missile programs; involved pushing programs into the production phase as rapidly as possible.

LAR Liquid Propellant Aircraft Rocket.

Lark BuAer missile for shipboard launch against aircraft.

Lark ramp 450-foot launching ramp at G-2 Range.

LASL Los Alamos Scientific Laboratory.

LB Range Bombing range in the China Lake complex, used primarily as an aircraft launcher testing area.

LCM Landing Craft, Mechanical.

LCU Landing Craft, Utility.

Little Boy Gun-type atom bomb relying on single-point detonation.

LOKI Liquid propellant rocket developed by the Army and canceled in 1952.

Long Track Original name for the Supersonic Naval Ordnance Research Track.

LST Landing Ship, Tank.

LTV Launching test vehicle for Terrier tests; also a manned amphibious tank.

Ma Manufacturing Division of BuOrd.

Ma9 Manufacturing Branch of BuOrd.

MCGMTU Marine Corps Guided Missile Test Unit.

Mesa-burning Property of a propellant tailored ballistically to have low temperature dependence and high energy level. The terms plateau-burning and mesa-burning came about because logarithmic plots of burning rates against pressure resembled desert tablelands in profile.

MESCAL Medium-Caliber Air-Launched Rocket program.

Meteor Early BuOrd semiactive-radar-guided missile developed under the technical direction of the Massachusetts Institute of Technology.

Mighty Mouse Nickname for 2.75-Inch Folding-Fin Aircraft Rocket.

MLC Military Liaison Committee.

Missile czar Term by which the OSD Director of Guided Missiles was known.

Mk 3 Bomb director, originally designed by the National Bureau of Standards in 1945.

Mk 8 All-weather, air-to-air and air-to-ground fire-control system for fighter aircraft.

Mk 10 Bomb director.

Mk 16 Nation's first fire-control system that used magnetic amplifiers.

Mk 24 Passive-acoustic homing mine.

Mk 27 Air-launched torpedo.

Mk 29 (IR) Official name for IRAH, infrared alternate head for Sidewinder.

Mk 30 (SAR) Official name for SARAH, semiactive-radar alternate head for Sidewinder.

Mk 32 Air-launched torpedo.

Mk 41 Air-launched torpedo.

Mk 42 Air-launched torpedo.

Mk 43 Air-launched homing antisubmarine torpedo.

Mk 176 Delayed-action fuze designed to penetrate an aircraft's outer skin, then detonate within the structure.

MLC Military Liaison Committee to Atomic Energy Commission.

Mobilhomes Inexpensive homes built in 1952; one of the first federally financed housing tracts in Ridgecrest.

Mojave B NOTS Aerial Gunnery Range, encompassing more than 300,000 acres southwest of Death Valley.

Mynatt houses Inexpensive homes built in 1952; one of the first federally financed housing tracts in Ridgecrest.

N-4 Solid propellant developed in 1949-50, the first NOTS-developed propellant to reach production.

N-5 Solid propellant developed in 1951 and showing the widest range of any mesa-burning propellant produced to that date in the United States.

NACA National Advisory Committee for Aeronautics, forerunner of NASA.

NAF Naval Air Facility.

NAMTC Naval Air Missile Test Center, Point Mugu, California.

NAKA Solid-propellant rocket developed by North American Aviation, Inc.

NAOTS Naval Aviation Ordnance Test Station, Chincoteague, Virginia.

NAS Naval Air Station.

NASA National Aeronautics and Space Administration.

NATC Naval Air Test Center, Patuxent River, Maryland.

National Military Establishment Central organization for the military services, created by the National Security Act of 1947 and replaced by the Department of Defense in August 1949.

NBS National Bureau of Standards.

Nickerson Report Critique of China Lake organizational structure, procedures, and management problems by five faculty members of Harvard Graduate School of Business Administration under the leadership of Clarence B. Nickerson. The first Nickerson Report was in 1949; the second was in 1951.

NODAC Naval Ordnance Data Automation Center; began operation in 1957.

NOL Naval Ordnance Laboratory, White Oak, Maryland, and Corona, California.

NOTS Naval Ordnance Test Station, China Lake and Pasadena, California.

NOTS 1 Naval Observational Television Satellite, referred to as NOTSNIK.

NOTS AM NOTS Air Missile, proposed in 1946; also called NOTS Interim Missile or Inyokern Air-to-Air Missile.

NOTSNIK NOTS Project (later Project Pilot), post-Sputnik effort by NOTS to loft a small satellite into orbit from a tactical aircraft.

NSC 68 National Security Council policy paper approved by President Truman in September 1950; NSC 68 proposed a radical expansion of both conventional and nuclear warfare capabilities.

NUOS Naval Underwater Ordnance Station, Newport, Rhode Island.

NWC Naval Weapons Center, China Lake, successor organization to the Naval Ordnance Test Station.

O-in-C Officer-in-charge.

OIR Navy Office of Industrial Relations.

OMAR Optically Maneuvered Air-launched Rocket, a beam-riding spin-off of the Sidewinder project.

ONR Office of Naval Research.

OP-05 Office of the Deputy Chief of Naval Operations for Aircraft.

OP-06 Office of the Deputy Chief of Naval Operations for Special Weapons.

OP-36 Atomic Defense Section, Office of the Chief of Naval Operations.

OP-51 Guided Missiles Division, Office of the Chief of Naval Operations.

OP-55 Air Warfare Division, Office of the Chief of Naval Operations.

OPDEVFOR Operational Development and Evaluation Force.

OPNAV Office of the Chief of Naval Operations.

Operation Black Magic U.S. effort to help the Nationalist Chinese Air Force develop the capability to fire Sidewinder.

Ordnance PG A graduate of Naval Proving Ground ordnance postgraduate training; referred to as a member of the Gun Club.

ORL Ordnance Research Laboratory, Pennsylvania State University.

OSD Office of the Secretary of Defense.

OSRD Office of Scientific Research and Development, set up in World War II under Vannevar Bush to coordinate scientific R&D efforts.

PBX Plastic-bonded explosives.

Peenemünde Secret Nazi rocket research and development center on the German Baltic coast during World War II.

PG School Postgraduate training for naval officers.

Polaris Pop-Up Series of tests to determine how underwater launch would affect the Polaris missile.

Project Atlantis Influential NOTS effort to estimate the number of ballistic missiles the United States would need to keep an enemy from striking back in the event of a nuclear war.

Project Argus High-altitude nuclear experiment designed to collect information on radiation in the earth's atmosphere.

Project Camel Code name for NOTS' involvement in work on the first atom bomb; Camel included development, free-fall testing, and manufacture of the bomb's non-nuclear explosive components.

Project Mercury NOTS study of Jupiter S components; influenced establishment of the Polaris program.

Project Metcalf Summer study organized in 1951 through ONR contract with Harvard University and assigned to make recommendations among the Navy's competing infrared missile projects.

Project Nobska 1956 summer study of antisubmarine warfare that recommended that the Navy build Polaris.

Project Paperclip Post-World War II program that facilitated transfer to the United States of German science and technology, including some German scientists.

Project Pilot Official name for China Lake's satellite project NOTSNIK.

Project Red Hot Name the Air Force assigned to an August 1955 demonstration at Holloman Air Force Base of Sidewinder's capability to shoot down rockets.

PSAC President's Science Advisory Committee.

QUEZY Programming system, "quick and easy," invented by Bruce Oldfield to help early NOTS computer users learn how to program the IBM 701 computer.

R&D Research and development.

Ram BuOrd-assigned name for 6.5-Inch Antitank Aircraft Rocket.

RAMO Reverse OMAR; 1954–55 evaluation of a method for coding an optical beam, conducted by Eastman Kodak and Johns Hopkins University.

RAPEC Rocket-Assisted Pilot Ejection Catapult

RAT Rocket-Assisted Torpedo.

RCC Range Commanders Council, established as Range Commanders Conference in 1951.

RDB Research and Development Board of DoD, set up by the National Security Act of 1947.

RDT&E Research, development, test, and evaluation.

Re Assistant chief for research, BuOrd.

Re2b Fuze Research Development Section of Ammunition Branch, Research and Development Division, BuOrd.

Re3 Projectiles, Rockets and Ballistics Branch of BuOrd Research and Development Division.

Re6 Underwater Ordnance Branch of BuOrd Research and Development Division.

Re9 Guided Missiles Branch of BuOrd Research and Development Division.

REAC Reeves Electronic Analog Computer, first central computer at NOTS.

Rem Assistant director for nuclear applications, BuOrd Research and Development Division.

Reo Ordnance Sciences Branch, BuOrd.

Reorganization Plan No. 6 Eisenhower administration plan to reorganize the Executive Branch; enacted by Congress on 30 June 1953. Seen as a milestone in the trend toward centralization of R&D management in DoD.

Research Board NOTS management group responsible for reviewing technical programs and advising the technical director.

RETORC Research Torpedo Configuration, study that resulted in the EX-8 torpedo (later Mk 46).

Rew Air Weapons Branch, BuOrd.

Rex Planning, Coordination, and Analysis Branch, BuOrd.

Rexa Systems director, aviation ordnance (senior civilian position in Rex), BuOrd.

RIF Reduction-in-force, structured personnel cutback involving elimination of positions.

Rocket A tubelike device that obtains thrust through the ejection of hot gases through a nozzle at its rear.

Rollerons Gyro wheels on hinged tabs installed on Sidewinder wings to damp missile roll.

ROPAC Rocket Planning Advisory Committee.

SAM Surface-to-air missile.

Sandquist pyramids Concrete walls built on Charlie Range during World War II for tests of the Tiny Tim rocket.

SARAH Semiactive-Radar Alternate Head; also known as Sidewinder 1C.

SCR-584 Radar system used to track aircraft from the ground.

Shrike Antiradar missile, called ARM (Anti-Radiation Missile) at first.

Sidewinder World's first operational air-to-air infrared-homing missile, invented and developed at NOTS and named after the desert rattlesnake.

SNORT Supersonic Naval Ordnance Research Track.

Sparrow Navy supersonic beam-riding missile designed for use on carrier fighter aircraft.

SPO Special Projects Office, set up to run the Polaris program.

Spot "Aerial flashlight," experimental system including a simple command-control missile and a narrow-beam searchlight.

SUBROC Submarine Rocket.

Stovepipe management Management where the employee works in a narrowly defined area, reporting upward and receiving instructions flowing downward, with little to no communication or work sharing with others working on parallel tasks.

STV Supersonic Test Vehicle for Terrier tests.

Super, the Name referring to the hydrogen bomb in its theoretical phase.

SWPP Salt Wells Power Plant.

T-34 Soviet-made tank used by North Koreans in the Korean War.

T-70 Soviet-made tank used by North Koreans in the Korean War.

T-214 2.0-inch rocket manufactured by Thiokol and sponsored by the Air Force; in competition with Gimlet for funding.

T-Gimlet Modification of 2.0-inch Gimlet rocket to incorporate features of Air Force T-214 rocket.

Talos Ramjet missile based on Bumblebee specifications.

TBF Grumman Avenger torpedo bomber of World War II.

Team Mike Detachment M of Squadron VC-35, first to use the Mighty Mouse rocket in Korea.

TEG Technical Evaluation Group of the Research and Development Board Committee on Guided Missiles.

Terradynamics Analysis of the dynamics of earth penetration.

Terrier Solid-propellant, supersonic beam-riding missile; descendant of Bumblebee.

Title VIII 1949 addition to the National Housing Act that authorized the FHA to insure mortgages on private rental housing constructed to serve military installations.

TORPAC Torpedo Planning Advisory Committee.

Torque balance control Aerodynamic balance between a missile's fins and torque applied to the fins by the servo.

Triton Long-range ramjet bombardment missile.

Trygon Seagoing test platform officially termed Deep-Depth Launching and Test Facility. A later version became a landing craft, utility with a hull number.

TX-8 Version of Elsie nuclear penetration bomb worked on by Los Alamos Scientific Laboratory, with key components and processes assigned to NOTS.

TX-11 Follow-on version of Elsie nuclear penetration bomb.

Type F Alternate Sidewinder seeker assigned to Summers Gyroscope Company; used a gimbal-mounted gyro around a hollow core to allow a stationary lead-sulfide cell probe to reach through the optics system.

Typhun German unguided liquid-propellant air-to-ground rocket about 5 inches in diameter.

UNIVAC Universal Automatic Computer.

Uniterm File Terms accumulated by the Technical Library to describe NOTS reports; used in library searches.

UOD Underwater Ordnance Department.

USSR Union of Soviet Socialist Republics.

V-2 German long-range rocket used against London and other Allied targets in World War II.

VAL Variable-Angle Launcher, installed at Morris Dam for tests of torpedoes and other full-scale projectiles.

VC-5 Composite Squadron Five, Navy's first Atom Bomb Squadron.

VC-6 Composite Squadron Six, Navy's second Atom Bomb Squadron.

VT fuze Radio proximity fuze, invented at the National Bureau of Standards during World War II.

VX-3 Air Test and Evaluation Squadron Three, based at Naval Air Station Atlantic City, New Jersey.

VX-5 Air Test and Evaluation Squadron Five, established at Moffett Field in 1951 and moved to China Lake in 1956.

WACOM Women's Auxiliary of the Commissioned Officers Mess; now known by its acronym only.

Walleye NOTS-developed television-guided glide bomb.

Watson camera X-CZP-1 Ballistics Camera designed by Jesse Watson for use in the Thompson Laboratory instrumented indoor range.

Weapon A Antisubmarine depth charge, forward-launched under sonar direction from a ship on the surface.

Wherry Bill Legislation named for its sponsor, Senator Kenneth S. Wherry; passed in 1949 and designed to help relieve housing shortages in the vicinity of military installations by giving private builders special incentives to construct government housing.

Williams-Bingham houses Inexpensive homes built in 1952; one of the first federally financed housing tracts in Ridgecrest.

WSEG Weapons Systems Evaluation Group, set up in 1948 under the joint sponsorship of the Joint Chiefs of Staff and the DoD Research and Development Board.

X-6 Mesa-burning solid propellant put on the shelf after development of the more promising X-7.

X-7 Mesa-burning solid propellant with higher energy and higher specific impulse than its predecessor; produced in limited quantities in 1953 and intended for Zuni rocket.

X-8 Solid propellant developed in 1953; extended mesa- and plateau-burning propellants over the entire practical range of rocket-motor pressures and burning rates; used in Zuni and Weapon A.

X-9 Slow-burning double-base solid propellant developed in 1953 specifically for use in Sidewinder.

X-10 Solid propellant developed as a more energetic version of N-5 for use in Gimlet rocket.

X-11 Rapid-burning solid propellant developed as the gas generator for the Liquid Aircraft Rocket.

X-12 Mesa-burning propellant with rapid burning rate and wide pressure range; developed in 1956.

YFN Covered Lighter, non-self-propelled.

YFU Harbor Utility Craft, self-propelled.

Zuni 5.0-Inch Folding-Fin Aircraft Rocket; the last of NOTS' major air-to-air rocket development programs.

Appendixes

A. U.S. Naval Ordnance Test Station Organization, 1948

Officer-in-Charge

U.S. NAVAL ORDNANCE TEST STATION
INYOKERN, CALIFORNIA
POST OFFICE - CHINA LAKE, CALIFORNIA

16 December 1948

STATION ORDER NO. 33-48

Subj: Command, Staff and Departmental Organization of the Naval Ordnance Test Station, Inyokern, California.

I. Mission

The mission of the Naval Ordnance Test Station was defined in a letter by the Secretary of the Navy, Op13C-je, Serial 232213, dated 8 November 1943, as that of "a station having for its primary function the research, development and testing of weapons, and having additional function of furnishing primary training in the use of such weapons". The Bureau of Ordnance in a letter to the Commanding Officer, NOTS (A) NP36 dated 30 March 1944, placed special emphasis on the development of rocket weapons, guided missiles, and aviation ordnance, as well as the training operations necessary for proper use of new weapons.

It is the intention of this Station that its facilities will be so organized and operated as to insure the successful conduct of its research, development, and test program with effectiveness fully equivalent to that attained during the war by the OSRD groups working in the corresponding fields.

In order to accomplish the stated mission, it is necessary to attract and hold a staff of the highest caliber. To attract and hold such individuals, it is necessary to provide a working environment and encouragement of outside contacts comparable to the best found elsewhere.

II. Command

The Commander is responsible directly to the Chief of the Bureau of Ordnance for matters pertaining to management control and technical control, including non-military matters such as allocation of funds assigned, of work assigned, of personnel, establishment of operating methods, procedures, and organization of the Station. He is responsible to the Commandant, ELEVENTH Naval District, for matters pertaining to military command and coordination control including internal security, fire protection, administration of naval discipline, defense, disaster control, emergencies, public relations, and coordination and cooperation with other activities within the area. The Commander performs the functions of Senior Officer Present Ashore, and is delegated authority to convene boards of investigation. The use of the terms "Command", "Coordination Control", "Management Control" and "Technical Control" are in accordance with the definitions established by General Order No. 245.

III. Constitution of Authority

(a) Commander

The Commander is the head of the Naval Ordnance Test Station, subject in the performance of his duties to the Navy Regulations and existing competent directives. Because of (1) the primary function of this Station as a research and development establishment, (2) the high percentage of civilian population, and (3) the isolated location requiring residence on the Station of practically all employees, the administrative problems are complex and unusual. In order to assist the Commander, the following positions and boards are established to which the Commander will delegate the requisite responsibility and commensurate authority. Action under such authority is subject to review by the Commander.

(b) Deputy Commander

The Deputy Commander is the principal advisor to the Commander for the military components of the Naval Ordnance Test Station. He has primary cognizance over the following components of the organization as shown on the attached organization bill:

16 December 1948

Subj: Command, Staff and Departmental Organization of the Naval Ordnance Test Station, Inyokern, California.

- -

1. Air Facility
2. Industrial Relations Department
3. Public Works Department
4. Supply and Fiscal Department
5. Command Administration, which consists of the following components:

   a. Medical Department
   b. Dental Department
   c. Legal Office
   d. Chaplain's Office
   e. Communications
   f. Commissioned Officer's Mess
   g. Ship's Service Store
   h. Public Information Office
   i. Security Department
   j. Administrative Services
   k. Recreation Services
   l. Naval Barracks

The Deputy Commander is responsible to the Commander for the correlation and coordination of the components of the organization over which he has primary cognizance with the components of the organization over which the Technical Director has primary cognizance. He is jointly responsible with the Technical Director to the Commander for the correlation and coordination of the activities of the Naval Ordnance Test Station as a whole for the efficient and effective accomplishment of the mission of the Station.

(c) Technical Director

The Technical Director is responsible to the Commander for development and testing of weapons and the methods of conducting research. He will conduct projects in accordance with the priorities set up by directives from the Bureau of Ordnance. The Technical Director has primary cognizance over the following components of the organization as shown on the attached organization bill:

1. Aviation Ordnance and Test Department
2. Controlled Missiles Department
3. Design and Production Department
4. Explosives Department
5. Research Department

The Technical Director is responsible to the Commander for the correlation and coordination of the components of the organization over which he has primary cognizance with the components of the organization over which the Deputy Commander has primary cognizance. He is jointly responsible with the Deputy Commander to the Commander for the correlation and coordination of the activities of the Naval Ordnance Test Station as a whole for the efficient and effective accomplishment of the mission of the Station.

(d) Administrative Board

The Administrative Board shall consist of the Commander as Chairman, the Technical Director as Vice-Chairman, and such Department Heads and other persons as may be designated by the Commander. The Administrative Board shall propose administrative policy and procedures for the operation of the Station.

(e) Research Board

The Research Board shall consist of the Technical Director as Chairman, the Associate Directors, the Experimental Officer, and such Department Heads

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and other persons as the Technical Director may designate. The Research Board will review technical programs and advise the Technical Director with regard to their establishment and conduct.

(f) Associate Directors

There are hereby established two Associate Directors, one for Research and one for Engineering. They will act as advisors and consultants to the Technical Director in the fields for which they are responsible. They will have direct responsibility to the Technical Director for planning and orientation of programs of Research and Engineering. Also, the Technical Director will delegate to the Associate Directors responsibility for the direction of certain specifically designated phases of the technical program. In exercising responsibilities involving department operations they will deal with the heads of the departments concerned.

(g) Staff of the Commander

There is hereby established a station staff with two broad fields of function, one management, the other technical. The Staff shall have responsibilities to the Technical Director for its functions in the zones over which he has primary cognizance and similarly to the Deputy Commander for its functions in the zones over which he has primary cognizance. It shall be responsible to the Commander for its over-all functions. It shall be the duty of the Head of the Staff to coordinate all of the Staff functions. The Staff has no direct authority over the operating organization. It shall be given the prerogatives of securing information, making studies and formulating recommendations upon which action of the Technical Director, the Deputy Commander or the Commander may be based. The Staff will base its plans and recommendations upon the coordinated needs of the Station.

(h) Community Manager

There is hereby established the position of Community Manager. He shall control all matters which concern the operation, administration, and welfare of the community and its related activities. He shall establish the policy for the operation of the various activities of the community and which serve the community. He receives the authority for the establishment of this policy directly from the Commander. In providing the necessary services to the community the heads of the various departments concerned will act in accordance with the policies of the Community Manager.

(i) Officer-in-Charge, Pasadena Annex

The Pasadena Annex is an integral part of the Naval Ordnance Test Station, Inyokern. The Officer-in-Charge, Pasadena Annex shall be the direct representative of the Commander for the activities of the Station in the Pasadena area. He shall be responsible for the coordination of all activities of the Pasadena Annex. Each unit in the Pasadena Annex is an integral part of the basic department of the Naval Ordnance Test Station to which its activities are related and accordingly receives technical and management control from its parent department. The correlation and coordination of the units in the Pasadena Annex for the accomplishment of the mission of the Annex, however, is the responsibility of the Officer-in-Charge and he receives such authority directly from the Commander, Naval Ordnance Test Station. In order to coordinate the functioning of the supporting activities, as they relate to the Pasadena Annex, namely Public Works, Supply, Industrial Relations and Command Administration, the Officer-in-Charge shall exercise administrative authority over those activities as necessary to carry out his responsibilities.

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Subj: Command, Staff and Departmental Organization of the Naval Ordnance Test Station, Inyokern, California.

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(j) Operating Components

The operating components shown on the attached organization bill are:

1. Air Facility
2. Aviation Ordnance & Test Department
3. Controlled Missiles Department
4. Design & Production Department
5. Explosives Department
6. Industrial Relations Department
7. Public Works Department
8. Research Department
9. Supply and Fiscal Department
10. Command Administration

The Heads of the operating components are responsible for the direct operation and administration of their components in accordance with the directives and policies of the Commander, and existing laws and regulations. They exercise direct line authority over the various segments of their respective components, receive their authority for such direction from the Commander or from existing laws and regulations, and are directly responsible to the Commander for the performance of their components. In their operation, the Heads of the various components will normally receive instructions from the Technical Director or the Deputy Commander in those fields over which the Technical Director or the Deputy Commander have primary cognizance. Such instructions emanate from the Office of the Commander and have the full force and authority of orders and instructions issued directly by the Commander in person.

The various Heads of the operating components shall coordinate their various operations with the Heads of other components who are concerned or affected by the various operations. They shall by suitable routing of correspondence, by conference, and by copy of pertinent correspondence originating within their respective components keep the Staff informed of their operations wherein such operation has an effect on the coordinated operation of the Station.

IV. Organization

The organization and operation of the Naval Ordnance Test Station as outlined above, together with the Organization Bill attached hereto will be placed in effect by separate directive.

W. G. Switzer

W. G. SWITZER
Commander, NOTS

Distribution list No. 1.

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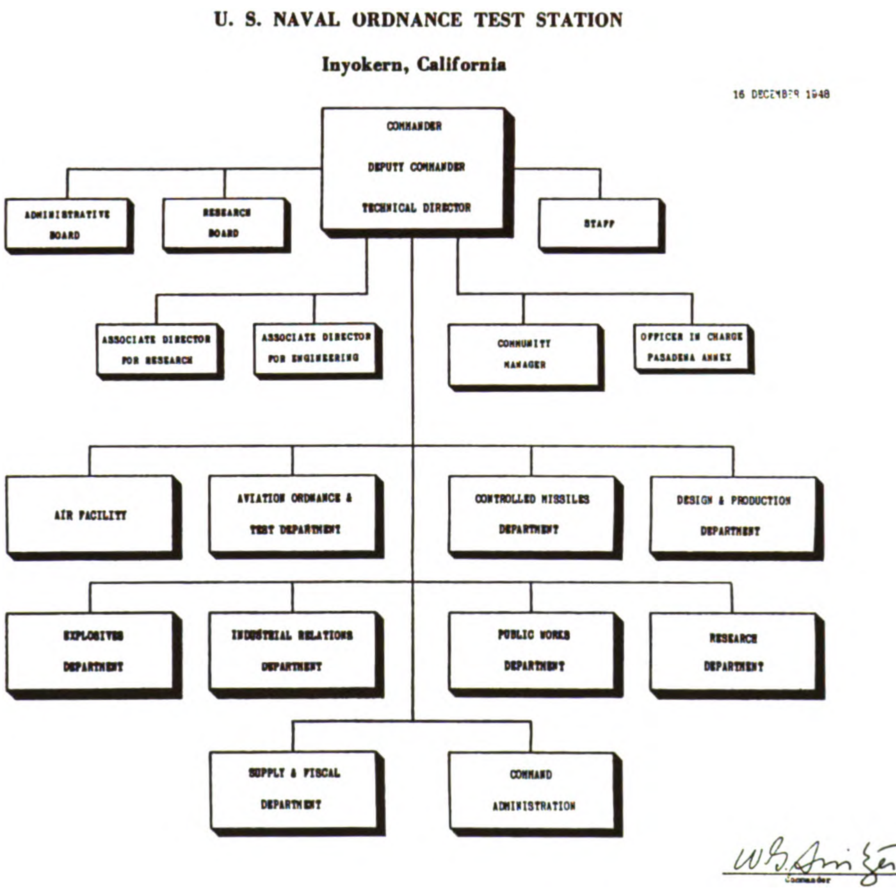
U. S. NAVAL ORDNANCE TEST STATION
Inyokern, California
16 DECEMBER 1948
COMMANDER
DEPUTY COMMANDER
TECHNICAL DIRECTOR
ADMINISTRATIVE BOARD
RESEARCH BOARD
STAFF
ASSOCIATE DIRECTOR FOR RESEARCH
ASSOCIATE DIRECTOR FOR ENGINEERING
COMMUNITY MANAGER
OFFICER IN CHARGE PASADENA ANNEX
AIR FACILITY
AVIATION ORDNANCE & TEST DEPARTMENT
CONTROLLED MISSILES DEPARTMENT
DESIGN & PRODUCTION DEPARTMENT
EXPLOSIVES DEPARTMENT
INDUSTRIAL RELATIONS DEPARTMENT
PUBLIC WORKS DEPARTMENT
RESEARCH DEPARTMENT
SUPPLY & FISCAL DEPARTMENT
COMMAND ADMINISTRATION
Commander

B. L.T.E. Thompson Awards, 1956–61

The L.T.E. Thompson Award was established in October 1956 as the Naval Ordnance Test Station's highest recognition for outstanding individual achievement. "In establishing this award, the Station pays tribute to the accomplishments of its first Technical Director," said the implementing instruction. "By his leadership, vision, and persistent effort, Dr. Thompson gathered at this Station a strong complement of outstanding men and women . . . The success of the Station in the field of ordnance has been in great part due to the initial guidance of Dr. Thompson and to his skill in integrating military and civilian personnel into an enthusiastic, effective group."

The award may be given for a single outstanding achievement or for continued excellence of performance in either technical or nontechnical areas. The number of awards given each year is not limited. Final selections are made by the commander and the technical director (now executive director) on the recommendation of an advisory panel appointed by the commander.

Many NOTS workers featured in this book were early recipients of the award.

8 November 1956

Dr. Louis T. E. Thompson "for his major role in the establishment and development of the U. S. Naval Ordnance Test Station. Through his vision, new concepts and objectives for an ordnance research and development organization were accepted and grew into reality. His contagious enthusiasm, vigorous drive, and unfaltering leadership have established the Station as one of the outstanding research and development organizations of the Department of Defense."

Dr. William B. McLean "for his extraordinary contribution to the defense of the Nation by executing the key role in the development of the Sidewinder guided-missile weapon system. His inspiring leadership, his matchless original conception, his persevering development resulted in a simple, economical, reliable, and effective system which pioneered current and future guided-missile development."

15 November 1957

Rear Admiral Sherman E. Burroughs, Jr., USN, "for his application of the concept of a government laboratory for ordnance research and development work who, as the Station's first Commanding Officer, by his inspirational leadership, dedication to and enthusiasm for his work, established an atmosphere for successful civilian-military team approach, and laid the groundwork for developing a facility of great importance to the Navy, the Department of Defense and the nation."

Commander John O. Richmond, USN (Retired) "for outstanding services as the Station's first Executive Officer and later Community Manager who, by his enthusiasm and dedication to the best interests of the Navy and the Station, was greatly responsible for the development of the Community. His efforts were of outstanding assistance in promoting, improving and maintaining the well-being, morale and efficiency of the personnel necessary to the accomplishment of the Station's mission."

Dr. Bruce H. Sage "for his able direction, dynamic enthusiasm, and farsighted tenacity in creating and constructing the China Lake and Salt Wells Pilot Plants at a critical time in the nation's defense. With great technical acumen, and without compromise of engineering principles, production standards, or safety, he erected and operated these important facilities of the Navy and the Atomic Energy Commission for the developing and processing of solid propellants and high explosives.

Dr. Gilbert B. L. Smith "for building one of the most outstanding research groups in the government, providing technical leadership and assembling a staff of unusual capabilities who have consistently worked at the frontiers of chemistry and applied the knowledge thus acquired to naval ordnance problems with vigor and foresight."

Captain Levering Smith "for his outstanding administrative and technical ability as exemplified by his performance as the Associate Technical Director for the Station where he provided insight and drive toward the establishment of a vigorous Navy program of research as shown by the development of the 2.75-inch aircraft rocket and methods for processing of solid propellant grains for rocket ordnance."

Haskell G. Wilson "for his outstanding work in promoting understanding between civilian and military personnel and who, as Head of Central Staff and later Associate Technical Director, has accomplished an excellent job of channelling civilian technical thinking into regulatory lines to conform to Bureau of Ordnance instructions."

14 November 1958

Captain Frederick L. Ashworth, USN, "for integrating the technical, administrative, and support groups into a team dedicated to fulfilling the

Station's mission, and, during his tenure as the Station's seventh Commanding Officer, creating widespread interest in the potential of this research and development activity, thereby brilliantly advancing the Station's prestige and upholding its mission."

Rear Admiral John C. Hayward, USN, "for his outstanding leadership and guidance as the Station's Experimental Officer in increasing the sensitivity of the Station to the needs of the fleet, thereby successfully integrating operational considerations and original research, and for advancing the Station through his interest in and enthusiasm for community affairs."

Dr. Howard A. Wilcox "for his signal enthusiasm, his diversified scientific skills, his original interdisciplinary thinking, and his ability to elicit the best from others, whereby he has overcome a series of formidable technical and administrative problems in the Station's research and development work."

5 May 1960

Dr. Ronald A. Henry "for his creative achievements in synthetic organic chemistry relating to solid propellants, for his contribution to the fund of knowledge of nitrogen chemistry, and for his pioneering work in high energy monomers and polymers."

Edward W. Price "for his outstanding research in internal ballistics, for his contribution to the understanding of the fundamental design parameters of rocket motors, and for his timely research in combustion instability."

16 November 1961

Dr. Frank E. Bothwell "for his vital contributions to the currently accepted concepts of a submarine-launched ballistic missile system. His work as Head, Weapons Planning Group, at Naval Ordnance Test Station was eminently instrumental in emphasizing the Polaris concept, including a great amount of detail on warhead and weapon requirements for strategic targeting."

Francis M. Fulton "for outstanding leadership in directing Naval Ordnance Test Station efforts in new areas of propulsion applied research and his initiative in exploring potentials in the field of limited warfare weaponry."

Leonard T. Jagiello "for his intuitive grasp of complex aerodynamic problems involved in the torque-balance canard control system, which has resulted in the successful design of a functioning Sidewinder airframe operating with consistent gain over the full range of dynamic pressures."

Franklin H. Knemeyer "for his significant technical contributions, leadership, and guidance on weapon-system development and his contribution to the formulation and implementation of the Free-Fall conventional ordnance program."

Dr. William S. McEwan "for his outstanding role in organizing the Station's program in chemical research, his maintenance of top-level productivity within that organization, and his directing of that research toward the Station's mission in regard to propellant systems for missiles. In addition, his publications in thermochemistry have brought him and the Station world recognition and have contributed to the advanced knowledge of chemistry."

Lawrence W. Nichols "for his singular achievements, extensive investigations, and precise analyses in the field of infrared research, specifically his investigations relative to IR radiations of targets and IR missile guidance systems."

Douglas J. Wilcox "for his leadership and technical contributions to the field of underwater weapon systems and especially for the ability displayed in the integration of a Navy-wide and industrial team for the successful accomplishment of the ASROC program."

Notes

Abbreviations

CARD	Collection of Archival and Reference Documents, Naval Air Weapons Station archives, China Lake, CA.
CPPR	Papers of Lieutenant Commander T. J. Christman (marked as historically significant Sidewinder documents), CARD.
CwPPR	Papers of Dr. W. Frank Cartwright (historically significant Sidewinder documents), CARD.
EPR	Papers of Dr. Emory L. Ellis, CARD.
McLPR	Papers of Dr. William B. McLean, CARD.
NL	Director of Navy Laboratories Oral History Collection, David Taylor Research Center, Annapolis, MD.
OA	Operational Archives, Naval Historical Center, Washington, DC.
RM	Naval Weapons Center Retrievable Manuscript, CARD.
RG38	Record Group 38, Washington National Records Center, Suitland, MD.
NWCV1	Albert B. Christman, *History of the Naval Weapons Center, China Lake, California, Vol. 1. Sailors, Scientists, and Rockets: Origins of the Navy Rocket Program and of the Naval Ordnance Test Station, Inyokern.* Washington: Naval History Div., 1971.
NWCV2	J.D. Gerrard-Gough and Albert B. Christman, *History of the Naval Weapons Center, China Lake, California, Vol. 2. The Grand Experiment at Inyokern: Narrative of the Naval Ordnance Test Station During the Second World War and the Immediate Postwar Years.* Washington: Naval History Div., 1978.
TPR	Papers of Dr. L.T.E. Thompson, CARD.
WPR	Papers of Dr. Newton E. Ward, CARD.

Unless otherwise stipulated, all letters, papers, and informal reports are in CARD.

Chapter 1

1. Wiegand, S-111, 21.

2. Thompson's background is recounted in more detail in the earlier volumes of this series. See NWCV1, 52–57; and NWCV2, 157–162.

3. A 1922 graduate of the U.S. Naval Academy, Parsons demonstrated exceptional scientific aptitude from the start. Starting in 1933 at the Naval Research Laboratory, he served as special assistant to Dr. Vannevar Bush in the development of the proximity fuze. Parsons also helped introduce the revolutionary new fuze to the fleet. In 1943 he became head of the Ordnance Division at Los Alamos, one of only four people reporting directly to J. Robert Oppenheimer. Parsons became deputy technical director of the Manhattan Project, and when the *Enola Gay* flew over Hiroshima on 6 August 1945, he was the weaponeer and bomb commander who armed and ordered release of the first atomic bomb. After World War II, Parsons was a member of three top groups: the Military Liaison Committee to the Atomic Energy Commission, the Weapons Systems Evaluation Group, and the Atomic Defense Division in the Office of Chief of Naval Operations. The latter assignment led to a strategic post as technical deputy to the commander of the famous Operation Crossroads weapons-effects tests. In 1951 he became commander of Cruiser Division Six in the Atlantic and Mediterranean, and in 1952 he became deputy chief of the Bureau of Ordnance, a position in which he used his influence to strengthen NOTS and the other Navy laboratories. He died on 5 December 1953, at the age

of 52. To learn more about this brilliant scientist and naval officer, read Al Christman's *Target Hiroshima: Deak Parsons and the Creation of the Atomic Bomb.*

4. Bernard Smith, a NOTS leader in 1948–60, recalled that when he became the technical director of the Naval Weapons Laboratory at Dahlgren in 1964, he benefited from Thompson's influence there. "By planting the seeds of his early dream for a fully integrated R&D activity seven decades before I arrived at Dahlgren, he made my job of completing the conversion of the Proving Ground into a valuable Naval R&D resource immeasurably easier," Smith wrote in an 8 July 1998 ltr to the author.

5. NWCV1, 73–75.

6. Ltr, LTET:cl, 9 Apr 1953, Thompson to Retirement Div., U.S. Civil Service Commission, Washington, DC (TPR). See also NWCV2, 244.

7. A note from Rear Admiral Frederick I. Entwistle, who had just been designated BuOrd's next deputy chief for research, congratulated Thompson on his "higher and justified status," which Entwistle viewed both as evidence that "your own status appears to be more permanently and definitely that of the Scientific Director" and as cause for optimism "in regard to the probabilities of the successful consideration of our peacetime scientific work." Ltr, 7 Aug 1948, Entwistle to Thompson (TPR).

8. A discussion of the problems that accompanied the Sykes command may be found in NWCV2, 224–239.

9. Vice Admiral John T. Hayward interview S-167, 14 Oct 1987, 10.

10. With Switzer's departure in September 1949, however, all of China Lake's commanders were captains until the arrival of Rear Admiral William J. Moran in October 1970.

11. Memo, 1 Nov 1948, "Change in Title of Officer in Command," Executive Officer to All Hands, NOTS.

12. Roderick M. "Rod" McClung interview S-188, 22 Mar 1991, 44–45.

13. The station's first principles of operation, as approved by Vice Admiral George F. Hussey, Jr., chief of BuOrd, on 21 October 1946, are reprinted in NWCV2, 403–404.

14. Hunter, S-95, 4, 6–7. Hunter, who received his doctorate in physics from Indiana University, followed six years of university teaching experience with war research in physics for the University of California San Diego and Caltech. After three postwar years at the University of Colorado, he came to China Lake in 1948. He spent two years on Thompson's staff, then moved to the Physics Division of the Research Department in 1950. Hunter subsequently served as head of Central Staff and head of the Propellants and Explosives Department, culminating his 30-year China Lake career as head of the Research Department.

15. Richmond, S-33, 87–88.

16. Ellis, S-203, 176.

17. Hayward, S-167, 14.

18. S-167, 14. Al Christman's review comments on the first draft also helped clarify the importance of the experimental officer to NOTS.

19. See NWCV2, 23–27. Hean's first assignment after he left NOTS gave him command of a transport squadron at the Naval Air Station, Alameda. Retiring in February 1951 as a rear admiral (from the position of commander of Fleet Logistics, Pacific Air Wing), Hean died the following August. Matthews and McIntire, *Draft History of the Technical Officer at the Naval Weapons Center*, 2-1 and 3-2; *Rocketeer*, 5 Sep 1951, 8.

20. Monroe's subsequent career included a tour as commander of the Pacific Missile Range, Point Mugu, and eventual rise to the position of chief of the Bureau of Aeronautics.

21. Jagiello, S-168, 31.

22. Smith, S-201, 3; and S-177, 16–17.

23. In 1938 theoretical physicist Max Delbrück joined Ellis in this effort. Delbrück's continuing research in bacteriophage over the following 30 years resulted in a 1969 Nobel Prize in medicine.

24. *Kern Valley Sun*, 25 Feb 1975; *Rocketeer*, 16 Jan 1952, 6.

25. S-177, 5–7.

26. Wiegand, S-111, 16.

27. S-177, 6.

28. Allison, "U.S. Navy Research and Development since World War II," *Military Enterprise and Technological Change: Perspectives on the American Experience*, 289–328.

29. On 19 September 1991, Hayward wrote the author, "There are no monuments to me in that far off desert place but if you sift some of the sands you might find a bit of my blood!" After he left China Lake, he served at Sandia Base, New Mexico; was the first to fly the Navy's AJ-1 and the first to command Composite Squadron Five; served as commanding officer of the escort carrier *Point Cruz* (CVE-119); and was commander of the Naval Ordnance Laboratory, White Oak. After service as the deputy CNO for R&D he took command of Carrier Division 2, the first nuclear-powered task force in naval history. He subsequently commanded the Antisubmarine Warfare Force, Pacific Fleet, then became president of the Naval War College, Newport, Rhode Island, remaining there until his 1968 Navy retirement. He became vice president for international programs at General Dynamics Corporation, later starting his own consulting business. He died on 23 May 1999.

30. Warner, S-102, 7.

31. Colorful descriptions of Sage are found in Virginia Pittinger, "'The great white father,' aka Dr. Bruce Sage," *Rocketeer*, 3 Jun 1993, 9; and in RM 1, *Salt Wells Pilot Plant Story 1945–1954*, 31–32.

32. Thompson, S-1, 45.

33. Station Order No. 33-48, 16 Dec 1948, "Command, Staff and Departmental Organization of the Naval Ordnance Test Station, Inyokern, California."

34. Handwritten ltr, 19 Dec 1948, Thompson to Wallace Brode (TPR).

35. Although the organizational lists from 1949 to 1951 show blanks where the department head's name should be, Smith verified that he succeeded Sage as head of the Rockets and Explosives Department. "Part of the reason may have been that as far as the organizational charts were concerned, it was a civil service position," Smith speculated in S-177, 7. Sage didn't stay long in the associate technical director job, where he annoyed the independent-minded department heads by issuing orders they were ill-disposed to obey. Thompson reassigned Sage to a senior consultant job in July 1950; Sage continued as a NOTS consultant until mid-1956.

36. A succinct description of the station's departmental reorganizations is found in "Evolution of Technical Departments (NOTS-NWC) from 1944 to January 1970," compiled by A. S. Gould, Sr., for presentation to the Naval Weapons Center Technical Board, 28 Jan 1979.

37. Sewell, S-106, 4.

38. Frank H. Haymaker, "Test Dept. Growth Mushrooms Keeping Pace With Weapons," *Rocketeer* special issue, 8 Nov 1955, 11.

39. NOTS TM 1782, *Early Guided-Missile Testing at NOTS (1945–1951)*, 36.

40. Throner and his cohorts eventually worked on more than two dozen destructor designs for all the services. By 1953 Throner's Explosive Ordnance Branch had designed destructors for Lark, Regulus, Sparrow, Meteor, Rascal, Shrike, Talos, Hermes, Viking, Corporal, and Terrier and was beginning work on a general-purpose destructor. At first the branch made prototype destructors at China Lake's Area R; as the program grew, the main shop in Michelson Lab also got into the destructor business. More information is available in Throner, S-233, 23–24; and in "Destructors for Guided Missiles," based on technical notes by William P. Farris, *Rocket*

Quarterly, Sep 1953, 11–18. Doig also pointed out in his review comments that China Lake still designs and builds flight-termination systems for test missiles and target aircraft.

41. NOTS TM 1782, 38–40.

42. In 1951 safety considerations and a higher-priority need to use China Lake ranges for tests of the Terrier missile caused the bureau to locate another site for air-launching Meteors. The testing needs of BuAer's Sparrow I had caused NAMTC to acquire instrumentation that would match Meteor's testing needs exactly. Accordingly, Meteor test activities moved to Point Mugu in January 1952, thus terminating the station's involvement in the program. NOTS TM 1782, 41–44.

43. NOTS TM 1782, 40–41.

44. White, *Interpretive History of the Pacific Missile Test Center*, 41–42.

45. NOTS TM 1782, 2–13.

46. *Rocketeer* special issue, 8 Nov 1955, 8.

47. Research Board minutes, 31 Jan 1949, 1.

48. RM-3, *Technical History of the U.S. Naval Ordnance Test Station 1943–1953*, 130–133.

49. NWCV2 discusses the design and construction of the China Lake Pilot Plant and of the station's other pilot plant, Salt Wells, site of explosives-development work for the Atomic Energy Commission (136–147, 206–221). A useful overview of solid-propellant work at NOTS is given in NOTS 1459, *Solid-Propellant Applied Research and Development at NOTS*. In *The China Lake Propulsion Laboratories*, Robbins and Feist provide a history of CLPP and its work. The static test stands in the area were precursors to massive test stands built to support the Polaris and Trident programs. See also "East of Eaton: The Story of the China Lake Propulsion Laboratories," a 38-minute video available from the China Lake Museum Foundation.

50. RM-3, 268–270.

51. On 30 May 1945 the field acquired its name in honor of Lieutenant John M. Armitage, who lost his life during a 1944 test of the Tiny Tim rocket. The field at Inyokern still exists today as Inyokern Airport and serves the Indian Wells Valley with several commercial flights per day. For more about the early days at Harvey Field, see NWCV2, 87–93.

52. Manuscript, "U.S. Naval Air Facility History," Vol. 1, scrapbook, loose-leaf.

53. Memo NP45-181/A21 RKF:rej Serial: 011, 22 Oct 1952, Commanding Officer, U.S. Naval Air Facility, to CNO (Aviation History and Research Section), 6. Staffing statistics, from NAF scrapbook, are for the number of men stationed at NAF when Armitage Field was officially commissioned in May 1947.

54. S-177, 29–30.

55. Leroy Doig review comment, July 2005.

56. RM-3, 78; NOTS paper, "Conference With Aeronautics Committee of the R.D.B., 1 February 1949—0830 to 1000, Conference Room, Michelson Laboratory," 17.

57. Research Board minutes, 28 Jun 1948, 2; 19 Jul 1948, 2.

58. Wiegand had earned three degrees in chemical engineering at the University of Michigan and had accumulated a year of experience as a chemist at duPont when war broke out. Beginning active duty with the Army Ordnance Department in 1942, he served three years at the Ballistic Research Laboratory, Aberdeen Proving Ground, Maryland. He arrived at NOTS in 1946 and moved up within the Rocket Department to become its associate head in 1952. He left in 1953 to accept a position at the Southwest Research Institute, San Antonio, Texas.

59. Wiegand, S-111, 12–13.

60. Ellis, S-203, 20; RM-3, 39–40.

61. Paper, Expl Dept. (6001) Reg 75077, 11 Nov 1949. Doig commented during his July 2005 review that the BOMROC 5-inch bombardment rocket and loader/launcher system that evolved from the station's spin-stabilized rockets was later used effectively in Vietnam.

62. NWCV2, 190–196.

63. Patton review comment. A graduate in mechanical engineering from the Carnegie Institute of Technology, Patton was working as a real estate agent when he got a job at NOTS in 1947. He spent about six months at the Pasadena Annex until housing could be found at China Lake.

64. *Naval Aviation Confidential Bulletin*, Jan 1949, 27 (OA); Wiegand, S-111, 1. Double-base powders contain two energetic ingredients: a nitrated high polymer (nitrocellulose) and an explosive plasticizer, usually nitroglycerin.

65. Further information about White Whizzer and other early Caltech rocket programs may be found in Price, Horine, and Snyder, "Eaton Canyon: A History of Rocket Motor Research and Development in the Caltech-NDRC-Navy Rocket Program, 1941–1946." Price, who began work in rocket propulsion at Caltech in 1941, arrived at China Lake in 1944. As a NOTS employee, he was a physicist in the Research Department, moving up to head the department's Aerothermochemistry Group in 1957. He was the 1960 recipient of the L.T.E. Thompson Award, the station's highest honor. See Appendix B for the citation.

66. McEwan noted in his review comments that the Navy had to build another such plant toward the end of the Vietnam conflict when the stockpiles of 2.75-inch rockets had been exhausted. By that time, a commercial market was using all the output of the previous plant. McEwan, who was a Rhodes scholar at Oxford University before he earned his Ph.D. at Harvard University, was in the U.S. Army Air Forces during World War II and rose to the rank of major, achieving renown for bombing studies he performed while he was in the Army. He arrived at NOTS in 1947 and became head of the Chemistry Division of the Research Department in 1954. He retired in 1976 and since then has pursued a successful second career as a sculptor.

67. *Naval Aviation Confidential Bulletin* Jan 1949, 27–28 (OA); paper, "Status of Major Programs, Naval Ordnance Test Station, 23 November 1949," compiled for Gus Lee Task Group, 2; Starnes Co. draft report, *Development History of the 2.75-Inch Folding-Fin Aircraft Rocket*, Chapters 3–11, 3 Feb 1954, 43–63, hereinafter referred to as Starnes 2.75-inch FFAR report.

68. Paper, Expl Dept. (6001) Reg 75077, 5. Ed Price noted in his review comments that a 3.15-inch Caltech rocket in 1943–44 saw similar antisubmarine use.

69. In a 1949 briefing, Albert S. Gould noted that externally carried stores on the Lockheed P-80A (the first U.S. jet-propelled combat aircraft) resulted in a "corresponding decrease in speed of from 100 to 125 m.p.h. at 30,000 to 40,000 feet, which is not acceptable." NOTS paper, "Conference With Aeronautics Committee of the R.D.B., 1 February 1949—0830 to 1000, Conference Room, Michelson Laboratory," 15–16.

70. "Aircraft Rockets," *Naval Aviation Confidential Bulletin*, Oct 1948, 30–31 (OA); NWCV2, 295; NAVORD Report 2059, NOTS 754, *For Pilots Only: Pilots' Handbook of Rocketry*, USNOTS, Inyokern, China Lake, Oct 1953, 9–11.

71. "Recent Trends in Navy Designs," *Naval Aviation Confidential Bulletin*, Jan 1949 (OA), 28.

72. Gould comments, 1 Feb 1949 RDB conference, 16.

73. NWCV2, 295–296; Starnes 2.75-inch FFAR report, 92. Development of the 3.25-inch fin-stabilized version, which had begun in early 1946, was abandoned by late 1947, since the rocket was too large to be practical in the newer combat aircraft of the day.

74. Starnes 2.75-inch FFAR report, 87–88.

75. This aircraft became the delta-wing F4D Skyray, which originated on the drawing board of aircraft design genius Edward H. Heinemann, chief engineer, El Segundo Division, Douglas Aircraft Company. He was also a 1953–57 member of the NOTS Advisory Board. According to an August 1951 article, "Fustest With Mostest" (*Naval Aviation Confidential Bulletin*, 18

[OA]) the 2.75-inch FFAR was originally intended to be the only armament the Skyray would carry, but uncertainty over whether rocket development would keep pace with that of the aircraft caused alternate provisions for four 20mm guns.

76. Memo S78-1(119)(Re3), 22 Mar 1948, "Small Caliber Folding Fin Air-to-Air Rocket," Chief, BuOrd, to Commanding Officer, NOTS, 1–3. This memo also canceled a 2.4-inch fixed-fin rocket, explaining that "the Bureau has never considered this type of round for service use since the limited space in aircraft would not permit carrying a sufficient number of them for effective combat use."

77. Wiegand review comments, 16 Sep 1998.

78. RM-3, 42.

79. In 1951 Terry, the creator of "Terrytoons," sent the station a cartoon of Mighty Mouse riding his namesake rocket (*Rocketeer*, 28 Nov 1951, 8).

80. RM-3, 53–54.

81. Camp, Elliott, Carlton, and Wiegand, "Station Has Had Leading Part in Development of Small-Scale Solid Propellant Manufacturing," *Rocketeer*, 14 Jan 1955, 6.

82. Starnes 2.75-inch FFAR report, 48; Encl. 1 to memo, 4004/AD:ad Reg 401279, 3 Feb 1954, "2.75-Inch Development History," Associate Head, Rocket Dept., to distribution.

83. Draft Advisory Board minutes, 22 Aug 1949, 2–3. Doig review comments, July 2005.

84. NOTS 1459, 21; RM-3, 94–95. The station also sent 1,000-pound test lots to the Naval Powder Factory, Indian Head, Maryland, for extrusion into finished grains. Indian Head also inhibited the grains, loaded them in motors, and tested them.

85. S-1, 55; and S-15, May 1966, 14.

86. Memo NP36(Rex), 27 Jul 1948, "Expansion of Bureau of Ordnance activities in the field of evaluation and analysis," Chief, BuOrd, to Commanding Officer, NOTS (McLPR).

87. NOTS memo RD&TO (Dir), 17 Feb 1948, "Notes on Telephone Conversation with Dr. L.T.E. Thompson," Saylor to Warner and Bennett (McLPR); ltr, LTET/lap, 39 Mar 1949, Thompson to Compton (TPR).

88. Hanson W. Baldwin, "New Rocket 'Fleet' Tested on Desert," *New York Times*, 2 May 1950.

89. Memo (A)AGN/do, 3 Mar 1948, "Action Urgently Needed in Support of the Bureau of Ordnance Research and Development Centers," Chief, BuOrd, to Technical Directors via Commanding Officers, NOTS and NOL (TPR).

90. Research Board minutes, 25 Jul 1949, 1.

91. Research Board paper, "Summary of the Technical Program," 21 Jan 1950, 17. The paper appears to have resulted from a November 1949 work-prioritizing exercise.

92. Research Board minutes, 31 Mar 1950; Committee for the Evaluation of Physics in the Technical Programs, "The Role of Physics in N.O.T.S. Technical Programs: A Report to the Research Board," 7 Jun 1950. The committee defined active professional researchers as "those "claiming prime competence in research, whose biographies appear in 8th edition American Men of Science and who have published in open literature or NavOrd's [the bureau's formal reports] in 1949–50."

93. Glatt, *Demise of the Ballistics Division*, 29–30.

Chapter 2

1. Coombs and Greenwood, ed., *Cultural Resources Overview and Inventory Plan for the Naval Weapons Center, China Lake*, 23; ltr, 10 Jun 1948, to Mrs. William Stevens (TPR).

2. Yockey, S-214, 14.

3. The Carrs' grandson, Norman Carr, said that early Navy property acquisitions required the Carrs to move twice. "Grandpa took all things in stride, but Granny deeply resented the

Navy for several years. Salve was applied when one of the captains of the base realized what a rich resource was available in the persons of my grandparents. He bestowed them with honors and asked them to participate in the annual wildflower show." The family participated in the show for 20 years thereafter. "Pioneer Family Album Shared" by Norman Carr, *News Review*, Ridgecrest, 26 Aug 1992, A27.

4. *Rocketeer*, 30 Apr 1954, 1.

5. *Rocketeer*, 30 Apr 1954, 1; and 4 Jun 1952, 6; Ellis review comments.

6. *Rocketeer*, 4 Feb 1955, 6; Ellis review comments.

7. S-233, 49.

8. Patton, S-179, 81–82.

9. *Rocketeer*, 9 Jul 1952, 8.

10. The position of deputy commander was retitled executive officer in 1950. A management study, "Information Prepared for the Management Committee Task Force of Research and Development, Office of the Secretary of Defense" (12 Apr 1950), shows the number of employees as 4,294 civilian and 1,010 military.

11. Station Order No. 33-48, 16 Dec 1948, "Command, Staff and Departmental Organization of the Naval Ordnance Test Station, Inyokern, California."

12. Wiegand review comments.

13. Jackson, S-186, 89; Wiegand, S-111, 10.

14. "Operations Audit of the China Lake Post Office," by Bruce Lawrence, Commander's Staff, File A-3-2-1(72), 15 Oct 51.

15. Richmond, S-33, Jan 1967, 72.

16. *Rocketeer*, 18 Feb 1948, 3; and 19 Oct 1949, 1, 8; *Valley Independent*, Naval Weapons Center 25th Anniversary Edition, Ridgecrest, 9 Nov 1968, 17.

17. S-188, 22 Mar 1991, 66; *Rocketeer*, 20 Dec 1957, 1. Today, as AltaOne Federal Credit Union, the organization is going strong, with more than 500 million dollars in assets and offices in Ridgecrest, China Lake, and other communities in the Northern Mojave Desert.

18. *Rocketeer*, 8 Jun 1949, 1; and 5 Apr 1950, 1.

19. Commander, NOTS, msg in *Rocketeer*, 24 May 1950, 1; and 3 Sep 1952, 5.

20. Tina Knemeyer, S-204, 37–38.

21. Beulah Smith, S-177, 5; and S-201, 25.

22. WACOM—the former acronym now the name—began a thrift shop in 1953 and since then has donated hundreds of thousands of dollars earned in the shop to other nonprofit organizations in the Indian Wells Valley.

23. *Rocketeer*, 7 Jul 1948, 1, 8. Sandquist Spa was built in 1944 and named for Captain Oscar A. Sandquist, first officer-in-charge of construction. Before the Navy came, a family named Stairs lived at the spa and grew alfalfa and fruit trees there. The spa is now closed.

24. Lois Allan said her wedding to Wallace H. Allan was in "the lean-to to the Quonset hut, which was then the chapel." As for the reception, "All it cost was sugar coupons, which I gave to the chef there so that he could get enough sugar to make the wedding cake." S-210, 65.

25. *Rocketeer*, 27 Sep 1957, "Sylvia Besser Presented First Social Work Award in Area," 1–2; *Valley Independent*, Naval Weapons Center 25th Anniversary Edition, Ridgecrest, 9 Nov 1968, 17. The Desert Counseling Clinic, which grew from Desert Area Family Service, was replaced by the College Health Clinic in 1998.

26. Memo, 1 Apr 1952, "Discrimination," Ballie Wall, Jr. GS-4, to Commanding Officer, NOTS; ltr, NP45-11/P8 Ser 1566, 10 Apr 1952, W.V.R. Vieweg, Commander, NOTS, to Dr. Harold Klaser, President, Chamber of Commerce, Ridgecrest; ltr, 14 Apr 1952, Klaser to Vieweg.

27. McLane, S-202, 10–11.

28. Boyle, S-180, 11–12; see also S-210, 74.
29. Bernard Smith review comments, 8 Jul 1998.
30. S-204, 42; Eleanor Lotee, S-181, 6.
31. Peter and Polly Nicol, S-225, 56.
32. Taped recollections, Historical Society meeting, 5–6.
33. *Rocketeer*, 29 Dec 1948, 5.
34. Memo NP36 (Es2)WCT/lv, 12 Aug 1948, "Commissioned Officers' Mess, NOTS Inyokern, Calif., Request for redesignation of," Chief, BuOrd, to Chief of Naval Personnel; memo, Pers-516-JL6, NP (51) (P), 8 Oct 1948, " Establishment of the Commissioned Officers' Mess (Open), U.S. Naval Ordnance Test Station, China Lake, Inyokern, California—approval of," Chief of Naval Personnel to Commanding Officer, NOTS.
35. Hucek, S-223, 37–38; *Rocketeer*, 22 Sep 1948, 6, which itemized the club's amenities as "a combination record player, pool table, electric hot plate, refrigerator and coffee maker." Today the former CPO Club is a conference center.
36. *Rocketeer*, 10 Jan 1951, 8; Wilson, S-197, 13.
37. Jackson, S-186, 20. Representative Out of Bounds orders are NP45-8513/A2-11(3), Station Order No. 4-50, 10 Jan 1950; and 11ND Circular Ltr No. 50-43 (16 P18-1(1) Ser 456/16, 1 Aug 1950, Commandant, 11ND.
38. In 1952 the NOTS Concert Series became the NOTS Civic Concert Association, a nonprofit corporation operating today as the Indian Wells Valley Concert Association.
39. *Rocketeer*, 6 Oct 1948, 2.
40. S-195, 41. Junior professionals were new scientists and engineers who rotated through a year of orientation tours before settling into their permanent job spots.
41. Robinson manuscript autobiography; *Rocketeer*, 9 Jan 1952, 3, 40–41.
42. S-210, 10 June 1992, 69. Emphasis in the original.
43. *Rocketeer*, 22 Dec 1948, 7. The play's cast and crew list also included Emily Richmond, Albert S. Gould, Dr. Arthur L. Bennett, and Kenneth H. Robinson.
44. *Rocketeer*, 22 Mar 1950, 4. In late 1959 Burroughs High School moved to a site just outside the southern boundary of the station and the old Burroughs school became Murray Junior High School.
45. *Rocketeer*, 24 Nov 1948, 3. This modest museum was a precursor to the Maturango Museum, which began in October 1961 in a China Lake Quonset hut and which has grown into a flourishing museum in Ridgecrest.
46. Harrington, *Pinto Site at Little Lake*; *Rocketeer* 9 Feb 1949, 7; 15 Mar 1950, 7; 5 Sep 1951, 7. See also *Indian Wells Valley and Northern Mojave Desert Handbook*, 3–6. The location of the petroglyphs within the China Lake military reservation protects them from vandalism.
47. In November 1953, for example, more than 40 people attended a field trip sponsored by the Natural Science Club (*Rocketeer*, 6 Nov 1953, 8). The Maturango Museum succeeded in 1964 in getting the area designated a national landmark, and more members of the public could visit the sites, usually through field trips coordinated by the museum. Excellent treatises on the petroglyphs, their history, extent, and significance, are *Rock Drawings of the Coso Range*, by Campbell Grant, James W. Baird, and J. Kenneth Pringle, Publication 4, Maturango Museum, China Lake, 1968; and *Coso Rock Art: A New Perspective*, edited by Elva Younkin, Publication 12, Maturango Museum, Ridgecrest, 1998.
48. *Rocketeer*, 21 Sep 1956, 2, announced the appointment of a wildlife conservation council consisting of the Public Works officer, several other military representatives, and range guard Sewell "Pop" Lofinck.
49. *Rocketeer*, 21 Sep 1956, 2. Earlier incidents on NOTS ranges with automobile breakdowns and lost sportsmen caused a revision of the weekend hunting policy to allow only parties of two

or more vehicles. John Di Pol noted in review comments that similar trapping programs in the 1960s–70s had the purpose of extending and propagating the species by transporting chukars to suitable "no-hunting" habitats throughout the state.

50. According to Minchen "Mickey" Strang (in a Jan 1992 conversation with the author), workers at the Supersonic Naval Ordnance Research Track (which began operation in 1954) had a persistent problem with burros drinking water out of the track's water brakes. Test coordinators often had to "shoo" burros before they could run tests.

51. Ltrs, NP45-8513/N1-13 Ser 4646, 29 Nov 1950, Commander, NOTS, to Mr. Virgil L. Bottini, District Grazier, Bishop, CA; and NP45-8513/N1-13 Ser 4893, 14 Dec 1950.

52. Coombs and Greenwood, 150–151. Limited grazing on Navy land continues today.

53. Unattributed document, *NOTS Land Status*, 1 Jul 1958; Encl. 1 to memo, 61.310/JCB: cer, 7 May 1963, "Mojave 'B' Aerial Gunnery Range; withdrawal of public lands within, legislation concerning," Chief, Bureau of Yards and Docks, to Commanding Officer, NOTS.

54. Memo 29 Mar 1948, "Mojave Gunnery Range 'B', instructions for the use of," J. M. Elliott, Commanding Officer, NAF, to all attached pilots.

55. Memo NA/F41-10(Mojave) ND11-KEV/Wd Ser 31436/44K, 7 Jun 1948, "Mojave Gunnery Range 'B', San Bernardino County, California—Revision of Boundaries," Commandant, 11ND, to Chief, Bureau of Yards and Docks.

56. *Rocketeer*, 20 Sep 1950, 7.

57. Charles E. Van Hagan, foreword to Lofinck, *Mojave Desert Ramblings*, iii–vii (now out of print). An excellent article on Lofinck may also be found in *Rocketeer*, 20 Sep 1950, 7; although *Rocketeer* editor Don Yockey modestly omitted his own byline on this story, he later cited the interview with Lofinck as one of his favorite career memories.

58. Lofinck, *Mojave Desert Ramblings*, 51–52; *How It Was*, Historical Society of the Upper Mojave Desert, Ridgecrest, 1994, v, 26–30.

59. *Rocketeer*, 23 Jan 1952, 1.

60. In 1962 Lofinck decided to return to civilization, and Captain Charles Blenman, Jr., NOTS commander, transferred the grizzled range guard to the Public Information Office, where he made a place for himself as the writer of a weekly column for *The Rocketeer*. He died 13 Nov 1971 at Furnace Creek Ranch, Death Valley, where he was attending a Death Valley '49ers encampment.

Chapter 3

1. *Rocketeer*, 7 Jul 1948, 1. Among the dignitaries in attendance were two GT&R officials who subsequently rose to positions of authority within the Department of Defense. Dan A. Kimball, vice president for GT&R's Akron operations, was later Secretary of the Navy (1951–53). Trevor Gardner, vice president in charge of the California GT&R group, became Air Force special assistant for research and development (1953–55) and assistant secretary of the Air Force for R&D (1955–56).

2. NWCV2, 228–231; *Rocketeer*, 7 Jul 1948, 3.

3. RM-3, 280–282; "Pasadena Annex Has Vital Role" by Margery Ross, *Rocketeer* special issue, 8 Nov 1955, 5.

4. NOTS 1130, *NOTS Ordnance Test Facilities 1955*, NOTS, China Lake, Oct 1955; Campbell, S-174, 25 Jan 1989, 8.

5. The VAL construction story is succinctly and entertainingly told in NWCV2, 300–302.

6. Undated brochure, "Science and Underwater Ordnance in Perspective," NOTS Pasadena.

7. Rocketeer, July 7, 1948, 2.

8. Bruce Wertenberger, interview S-195, 40.

9. William B. McLean, "The Sidewinder Missile Program," Chapter 15 in *Science, Technology, and Management*, edited by Fremont E. Kast and James E. Rosenzweig, McGraw Hill, 1962, 169. So convinced was McLean of the value of such isolation that after he became the technical director in 1967 of the Naval Ocean Systems Center (NOSC, now the Naval Command Control and Oceanographic Surveillance Center), China Lake's sister laboratory in San Diego, he proposed moving many NOSC people to an isolated location on Oahu.

10. D. A. Kunz interview S-104, 23 Oct 1975, 8. Some of GT&R's early management problems at the Pasadena Annex are discussed in NWCV2, 228-31.

11. James H. Jennison interview S-99, 23 Oct 1975, 21-22.

12. Pasadena "Principles of Operation," 26 Feb 1948.

13. When John Cox reviewed this book, he commented that Hilton appeared not to be as comfortable with civilians as his successor and some of the annex' other military leaders were.

14. Rocketeer, 22 Dec 1948, 2; Jennison interview S-99, 9.

15. Paper, "Summary of Comments on Harvard Report by N.O.T.S. Personnel," prepared by Dr. Hugh Hunter, summer 1949, 5 (McLPPR).

16. Cox review comments on the first draft, June 1998.

17. Research Board minutes, 12 Apr 1948, 2.

18. Ltr, WHS:jj, 16 Aug 1948, Saylor to Thompson (TPR).

19. Memo RD&TO Expl Dept. Reg 36600, 30 Jun 1948, "Travel Report: American Ordnance Association Meetings in Detroit, Mich., and Conferences at Bureau of Ordnance, Washington, D.C., Covering Period 6–17 June 1948," W. E. Patrick to Head, Explosives Dept.

20. Memo JHW:mh, RD&TO, RDU, 10 Nov 1948, "Suggestions for Organization for NOTS," Wayland to Warner.

21. *Rocketeer*, 29 Dec 1948, 8.

22. S-99, 23 Oct 1975, 19–21.

23. Advisory Board minutes, 22 Aug 1949, 7–11.

24. "Summary of the Underwater Ordnance Department Program for the NOTS Advisory Board," 25 Oct 1951, 6–7 (TPR).

25. *Rocketeer* special issue, 8 Nov 1955, 5.

26. Boyd, S-220, 85.

27. Memo NP45-12/A3-1, 11 Jun 1949, "Organization and problems of operation in Pasadena," Technical Director to Head, Underwater Ordnance Dept. (TPR).

28. Research Board minutes, 12 Sep 1949, 2.

29. Msg, L24 A7 ND11-02/Me, 8 Apr 1949, "Policy on Public Relations regarding Cut-Back," Commandant's Office, 11ND, to special distribution (all activities in 11ND).

30. Research Board meeting expanded minutes, 3 Oct 1949, 28–30.

31. Memo NP45-651/P16-1(8) Ser 3225, 11 Aug 1950, "Career and disabled employees; Separation of in reduction in force," Commander, NOTS, to Office of Industrial Relations.

32. *Rocketeer*, 30 Aug 1950, 3.

33. S-174, 14.

34. S-99, 24–25.

Chapter 4

1. "From Gadgeteering, A Guided Missile Weapon With Complex Functions but Simple in Design," *Rocketeer*, 19 Oct 1956, 1.

2. McLean's youngest brother, Rev. Robert N. McLean, Jr., carried the family's pastoral calling on into the third generation. The middle brother, John G. McLean, became a member

of the faculty of the Harvard Graduate School of Business Administration and successively vice president, president, and chairman of Continental Oil Co.

3. LaV McLean, DNL-T-23-80, 3 (NL).

4. LaV McLean, S-210, 1.

5. The cause of Clara McLean's death was a ruptured appendix.

6. S-210, 2.

7. S-210, 5–6. The two sons born in Washington, DC, were Billy (1942) and Don (1944). The third son, Mark, was born in 1950 in China Lake.

8. The work at NBS was on one of two separate radio proximity fuze projects. A VT fuze for rotating projectiles was developed for the Navy at the Department of Terrestrial Magnetism, Carnegie Institution, and later at the Applied Physics Laboratory, Johns Hopkins University. The NBS fuze was for nonrotating weapons and was for the Army Air Corps.

9. David Rugg, Sidewinder History (Manuscript), prepared from the files of the Sidewinder Program Office, 1971–74, 37. Subsequently referred to as Rugg ms.

10. Cochrane, *Measures for Progress. History of National Bureau of Standards,* 401–403. In S-141, 11–12, Frederick C. Alpers, an NBS employee who later worked at China Lake, commented on problems with the missile in combat, among them warping of the plywood wings. In addition, since the Bat radar was tied to the missile, "the only way to search the ocean was to weave the plane back and forth . . . to point the missile in all directions because of the strap-down radar on the front."

11. A native of Kharkov, Russia, Rabinow arrived in America at age 11; he began work at the National Bureau of Standards in 1938 and left there in 1954 to form Rabinow Engineering Company (RABCO), later acquired by Control Data Corporation (of which he became vice president). When Harmon Kardon Corporation acquired RABCO in 1972, Rabinow rejoined NBS, where he was chief engineer of the National Engineering Laboratory until his 1975 retirement. Rabinow patented hundreds of devices, notably automatic clock regulators formerly used in all American automobiles, the first letter-sorting machines adopted by the U.S. Postal Service, and the magnetic particle clutch. Cochrane notes (460) that interest in this clutch, which had potential applications in a wide variety of mechanisms, was so great that within a year after its invention, nearly 2,000 industrial engineers visited NBS to learn more.

12. Rabinow, *Inventing for Fun and Profit,* 38–41; McLean, S-88, 16 Nov 1973, 1.

13. Rabinow, 29–30.

14. LaV McLean recalled in S-113, 18 Mar 1980, 47, that Captain (later Rear Admiral) Kenneth H. Noble, then BuOrd's assistant chief for research, abetted Thompson in his recruiting efforts. Bill McLean thought (in S-97, Jul 1975, 2) that the person accompanying Thompson might have been the chief of the bureau, Rear Admiral (later Vice Admiral) George F. Hussey. In either case, the high level of interest in McLean is indicative of the esteem members of the ordnance community had for him.

15. Halperin, Clapp, and Kantner, "Organizational Interests," 214–215.

16. The number of postwar missile projects cited by Armacost in *The Politics of Weapons Innovation*, 27, is 114; York and Greb, in their seminal article, "Military Research and Development: a Postwar History," 19, cite the number 35 as "useful estimate of the number of missile programs being supported directly by the government in the period 1949–1950," noting also that "Many other smaller efforts were being supported indirectly through overhead, deductible R&D, and similar means."

17. *Review of Navy R&D Management, 1946–1973,* by Booz, Allen & Hamilton Inc., 16 (subsequently referred to as Booz, Allen R&D management study); York and Greb, 14.

18. Allard, "Interservice Differences in the United States, 1945–1950: A Naval Perspective," 75. See also Armacost, *Politics of Weapons Innovation*, 37–38.

19. Booz, Allen R&D management study, 19.
20. OPNAV Instruction 0390.1, "Navy Research and Development Coordination," Office of CNO, 25 May 1951, 1–4 (Post 1 Jan 46 Command File, OA).
21. York and Greb, 15–16; Kelly, "Research Advisory Committees," 58–65 (McLPR); Neufeld, *Ballistic Missiles in the United States Air Force, 1945–1960*, 53.
22. Booz, Allen R&D management study, 187–197.
23. Quoted in Neufeld, 52.
24. Neufeld, 52–53.
25. Station Memo No. 9-50, NP45-13/A3-2(2), 10 Feb 1950, "Sixth Senior Personnel Conference, 9 December 1950; minutes of," by Code 10, 4.
26. L. R. Hafstad, "The Government's Program in Science," address at Station Theater, NOTS, 25 Jul 1949, 9–10 (TPR).
27. S-15, 10–13.
28. Memo NP45/A1-1(2)/R/erm Ser 0825, 30 Aug 1946, "Air-to-Air Guided Missile," J. B. Sykes, Commanding, to Chief, BuOrd; NWCV2, 1978, 288–289.
29. S-88, 25.
30. Memo MEG30/2 (Item 6 GM 2/14), (Rex-a) USB/ob, S78-1(126), 2 Aug 1948, "Comments on the Technical Evaluation Group Report GM 50/4.7, Inyokern Air-to-Air Missile," Chief, BuOrd, to Chairman, Committee on Guided Missiles, RDB, via OP-57 (RG38).
31. Memo 754/PHF:blm Ser 01069, 9 Aug 1962, "Interference No. 92172; McLean (Navy Case 22995 [Target Seeking Gyro]) v. Osborne (Patent No. 2,948,813)," P. H. Firsht, by direction, to Chief of Naval Research; In the United States Patent and Trademark Office Before the Board of Patent Interferences, McLean v. Osborne, Interference No. 92,172, Brief on Behalf of William B. McLean, Filed with Patent Office 20 May 1975.
32. Report GM 50/4.7 MEG 30/1, 28 May 1948, "Inyokern Air-to-Air Missile," by Technical Evaluation Group, Committee on Guided Missiles, RDB (RG38).
33. Memo MEG30/2, 2 Aug 1948.
34. Memo S78-1(126)Re9d-RBD/gep, 4 Aug 1948, "Air-to-Air Guided Missile, Development Program for," Chief, BuOrd, to Commanding Officer, NOTS.
35. Memo NP45/a1-1(1)(RD/AHW,WHS,JHH) Ser (0530), 10 Nov 1948, "Air-to-Air Guided Missile, Development Program for," Commanding Officer, NOTS, to Chief, BuOrd (McLPR); Research Board minutes, 8 Nov 1948, 1. The committee was under the direction of Dr. Arthur H. Warner and included Commander James H. Hean, Dr. John W. Odle, Dr. William B. McLean, and Dr. Hugh W. Hunter.
36. Interview with McLean and Wilcox, "Air-to-Air Interception," NOTS 2068, *Weapons Journal of Research, Development, and Test*, Vol. 1, No. 1, 8.
37. Memo NP36 Re9a-MF/gep, 12 Nov 1948, "Air-to-Air Missile—Task Assignment of," Chief, BuOrd, to Commander, NOTS (WPR).
38. Rugg ms, 31–32.
39. NOTS 2068, 8.
40. Report MEG 9/6, Log No. 31848, Copy No. 108, 15 Oct 1948, "Summary Report of the Technical Evaluation Group 6th Meeting, 14–15 October 1948," by Technical Evaluation Group, Committee on Guided Missiles (RG38).
41. Doig noted in review comments that starting in the 1970s China Lake had significant involvement in Sparrow, providing the technical expertise to expand and improve on the missile's capability and participating in the development of an advanced version of the missile.
42. Research Board minutes, 7 Feb 1949, 3.
43. Telex NR F 44 24 Feb 1949 Priority 1335 E, A. Vazsonyi to A. L. Bennet [*sic*]. This telegram pertaining to the NOTS Air Missile appears to have found a place in China Lake lore

with one significant detail changed. People remembered having seen such a message posted along the corridors of Michelson Laboratory, but the missile they recall the message referring to was Sidewinder. Although Sidewinder was certainly threatened with cancellation, that remembered telegram does not appear to exist.

44. Advisory Board minutes, 22 Aug 1949.

45. Dr. Howard A. Wilcox, "Research Problems Associated With the Development of Sidewinder," speech presented at ONR symposium, 19–20 Mar 1957, 5.

46. RM-3, 135–136; Station Journal, Dec 1955.

47. McLean, untitled paper for presentation at the National Advanced Management Conference, 5 Sep 1962, Seattle, Washington, 6–10; later revised and reissued as Chapter 15 of Kast and Rosenzweig, *Science, Technology, and Management.*

48. NOTS 2068, 6.

49. McLean, "Our Changing Mission," presentation to Annual Meeting, Missile and Astronautics Div., American Ordnance Assoc, China Lake, 8 Apr 1965, 1–2.

50. Sewell, S-106, 11. Sewell said Pierce would absorb the contents of dozens of books a day on whatever subjects interested him at the time.

51. McLean laboratory notebook #3, entry of 19 Nov 1947. Signatures of Herbert H. Hassenfratz on 19 November and I. H. Swift on 25 November verify that McLean also explained his concept to them.

52. S-88, 3.

53. Memo for file, MNM/754, 5 Mar 1963, "Individuals who may possibly prepare affidavits on McLean inventorship problem," interview in Ann Arbor with Commander Harry H. Hassenfratz, Q. B. Warner, interviewer. This memo is part of documentation Baltimore attorney Walter G. Finch accumulated to defend the validity of McLean's Sidewinder patents.

54. According to *Rocketeer,* 19 Oct 1956, 6, this early team included Lucien M. Biberman, Sydney R. Crockett, Jack Braitman, Donald Duckworth, Roger S. Estey, William A. Gey, Laurence W. Nichols, and Theodore R. Whitney. Woodrow Mecham and John Murray performed the early machining work.

55. Record of Invention, Navy Case No. 10626, "Target Seeking Gyro," signed by William B. McLean, 27 Dec 1948; NAVORD Report 1146, NOTS 201, *An Air-to-Air Target Seeker,* by D. T. Duckworth, Aviation Ordnance and Test Dept., NOTS, 11 Mar 1949, 1–4.

56. Warner, S-102, 9.

57. Memo RD&TO (Dir), 17 Feb 1948, "Notes on Telephone Conversation with Dr. L.T.E. Thompson," Saylor to Warner and Bennett (McLPR).

58. S-88, 6.

59. NOTS 2068, 6–7.

60. Record of Invention, Navy Case No. 10626; NAVORD Report 1146, NOTS 201, 1–4; McLean, S-88, 5. Ironically, the Hughes engineers found that oscillations in the Falcon missile were too severe to allow the engineers to take their own advice. They ended up incorporating a second gyro into their missile's design.

61. Ltr, 21 Dec 1948, Thompson to Parsons, 2

62. Compton, a renowned physicist, was president of the Massachusetts Institute of Technology at the time of his appointment. He was a prominent member of the nation's World War II scientific fraternity, having been wartime chief of OSRD's Office of Field Services.

63. Memo, "Cognizance," 10 Feb 1949, Parsons to Compton. Emphasis in the original.

64. S-21, 5 Nov 1966, 49.

65. Ltr, LTET/lap, 30 Mar 1949, Thompson to Compton (TPR).

66. Ltr, 19 Apr 1949, Compton to Thompson (TPR).

67. S-15, 11.

68. NOTS TM 452-5; Rugg ms, 48–53.
69. Research Board minutes, 3 Oct 1949, 20–21.
70. Infrared is defined as the region at the red end of the electromagnetic spectrum that radiates wavelengths just longer than those of visible light. The advantage of infrared radiation was that it usually offered a focused area on which a missile could home.
71. Rugg ms, 9–12, contains a brief overview of these programs.
72. Rugg ms, 6–9; ONR memo, EXOS:ONR:421 FBI:bb, 7 Jun 1948, Encl. A, "Minutes of Meeting Concerning 'Infrared Emission of Jet Engines' dtd 3 June, 1948," 3–4.
73. Nichols' basic and applied research on infrared radiation from military targets soon earned him an international reputation in the field. In 1961 NOTS honored these contributions by presenting him with an L.T.E. Thompson Award, the station's highest honor. See Appendix B for the citation.
74. Nichols, "Infrared Research for Development of Sidewinder," NOTS 2068, 37–38.
75. "Roger Estey was closely coupled with real problem areas. He looked at the things he could do that people would see as being useful," Hunter recalled in S-95, 12.
76. Wilcox, S-196, 76.
77. Rugg ms, 51, 63. Lucien M. Biberman and Estey jointly held the patent on the multislit scanner. See NOTS 2068, 47.
78. LaV McLean, S-113, 41.
79. Wilcox, S-112, 30–31.
80. Station Memo 17-50, NP45-12/A3-1, "Organizational Changes; delegation of responsibility," 21 Feb 1950, Commander, NOTS, to department, division, and section heads.
81. Rugg ms, 75.
82. McLean, S-97, 18.
83. Ward, S-94, 12; S-211, 28.
84. Maryon Ward, S-211, 90–91, 97.
85. S-211, 28, 85.
86. Ward, S-94, 42.
87. LaBerge, S-178, 1 Sep 1989, 1–2; *Rocketeer*, 1 Feb 1956, 1; Wilcox manuscript, "Reminiscences and Reflections Regarding the Sidewinder and Its Creator, Dr. William B. McLean," Installment 4 (SW-4), 7 (subsequently referred to as Wilcox ms). In 1956 LaBerge became the Sidewinder manager and head of the Missile Development Division of AOD. He left NOTS in 1957 to become director of engineering, Western Development Laboratories, Philco-Ford Corporation. After holding several top-management positions at Philco-Ford, he returned in 1970 to the position of NOTS deputy technical director. He became technical director of the Naval Weapons Center in June 1973, leaving three months later to accept the position of deputy secretary of the Air Force for research and development. Subsequently he became assistant secretary of NATO for defense support, under secretary of the Army, and under secretary of defense for research and engineering. After service on the staff at the Naval Postgraduate School in Monterey, he joined the Lockheed Corporation in Sunnyvale in 1981. He retired in 1989 as vice president for advanced planning. He died on 16 July 2004.
88. Cartwright, S-194, 45; *Rocketeer*, 8 Jun 1973, 1, 3. Smith became head of the Missile Branch, Aviation Ordnance Department, in July 1955, and after a series of increasingly responsible branch and division-head positions, he was head of the Systems Development Department in 1973–75. He then moved to Bedford, Massachusetts, where he was a weapons analyst with the Raytheon Company. He died in September 2001.
89. Wilcox ms, SW-1, 4.
90. S-196, 15–17. Wilcox succeeded McLean as manager of the Sidewinder program in February 1953, then became head of the Weapons Development Department in 1956 and

head of the Research Department in 1958. He left NOTS in early 1959 to become one of the two deputies to Dr. Herbert York, director of defense research and engineering. In late 1960 Wilcox set up the Defense Systems Division of the new General Motors Research Laboratories in Santa Barbara, returning briefly to China Lake in 1971 as a consultant to LaBerge. Author of more than 100 published articles, holder of seven U.S. patents, and recipient of numerous awards, Wilcox died in August 1994.

91. Chuck Smith in S-112, 6.

92. The B head was sometimes referred to as the "Biberman head" in recognition of the central role Luc Biberman played in its development. Biberman was one of the first technical employees to arrive at NOTS, starting at China Lake in 1944. He made numerous contributions to Sidewinder, receiving patents on guidance systems for Sidewinder AIM-9B through AIM-9H. After leaving China Lake in 1957, he became associate director of the University of Chicago Laboratories for Applied Science. In 1962 he moved to the Institute for Defense Analyses in Alexandria, Virginia, where he continued to build a distinguished reputation as one of the nation's foremost experts in infrared and electro-optical technology.

93. Ltr report, WBM/TAR/vms, 30 Jun 1950, "Local Project 583 Status Report of 1 March 1950–31 May 1950, Title Heat Homing Rocket, Cognizant Code 452."

94. Ltr, 15 Mar 1950, McLean to Mr. R. F. Wehrlin, President, Avion Instrument Corp., New York, New York; Contract No. N129S-68781, Schedule No. 32937, 19 Sep 1950.

95. AIC Report No. 257, "The Heat Homing Rocket," Avion Instrument Corp., New York, New York, 30 Jun 1950, 5–6.

96. Ltr, 28 Dec 1949, A. H. Warner, NOTS, to Commander Frederic A. Chenault, BuOrd (Re9a).

97. Informal paper, "Comments and recollections by Lucien M. Biberman, 11 Aug 52, Seeker Models Used in Sidewinder Missile Development," 1.

98. Swann, S-198B, 5.

99. S-196, 76–77.

100. Rugg ms, 44–45.

101. Rugg ms, 49, 55. McLean recalled that in 1950 he asked Henry Newburgh to begin with the magnets and other available parts from a firing switch that had been developed for the Tiny Tim 11.75-inch aircraft rocket and use them to build a magnetic generator of the type suggested by a group of visiting British proximity-fuze experts. Newburgh's generator soon surpassed the British version (Ltr, Code 01, 29 Apr 1963, Wm. B. McLean, Technical Director, to Mr. E. W. Schrader, West Coast Editor, *Design News,* Englewood, Colorado).

102. S-196, 12; Glatt, 11–12. The Glatt study notes that in the minds of many Ballistics Division employees, "the seeds of future reorganization of the Ballistics Division had been planted" on the day Jagiello moved to Sidewinder. According to Glatt, Wilcox said he was not creating a rival organization, but Ballistics Division personnel "viewed this development as their first really serious competition with their own organization and functions."

103. Wilcox ms, SW-1, 12.

104. Jagiello, untitled talk to China Lake Chapter, American Institute of Aeronautics and Astronautics, Ridgecrest, 15 Nov 1991.

105. Jagiello, S-168, 7, and his review comments; Meeker comments to the author, 23 Mar 1996. Meeker and others who worked with Jagiello said he called all his co-workers Moe.

106. S-178, 12

107. Jagiello, S-168, 57; Rugg ms, 69–74.

108. Parsons' scientific expertise was much in demand. He divided his time among three groups: the Military Liaison Committee to the Atomic Energy Commission, the Weapons Systems Evaluation Group, and the Atomic Defense Division in the Office of the Chief of

Naval Operations. See Al Christman, "Deak Parsons Officer-Scientist," *U.S. Naval Institute Proceedings,* 118/1/1,067 (Jan 1992) 56–61.

109. S-197, 34; see also the undated draft (in handwriting of McLean and Wilcox) written shortly after an 18 March 1952 meeting at BuOrd and attached to office memo, 20 Jul 1952, Lt C to Howie (CPPR). Despite its unofficial nature, the draft is useful because it offers an unusually complete overview of Sidewinder's early funding difficulties as documented by two important Sidewinder team members. Since the bureau officially recognized and funded Sidewinder in April 1952, the explanation was no longer needed, and the draft never reached final form.

110. Msg, Ø51929Z Oct 1950, BuOrd to NOTS Inyokern, Action, Technical Director.

111. McLean, S-97, 9; Research Board minutes, 17 Oct 1950, 5; and 3 Oct 1949, 20.

112. Plain, S-108, 6; *Rocketeer,* 19 Oct 1956, 3; memo, NP45-4012/Reg 85703, 28 Nov 1950. Others have commented that the flight profile of the missile sometimes resembles the slithering path of the snake, but that observation was apparently not a consideration in selecting the name.

113. Memo NP45-35 Ser 45, 23 Oct 1950, "Organization and Plans for Accomplishment of Project to Develop a Control System and Fuze for the HPAA Rocket," Head, AOD, to Technical Director via Associate Director for Research.

114. Memo NP45-15, 11 Nov 1950, "Heat Homing Rocket," Associate Director for Research and Development to Head, AOD.

115. Memo NP45-4012/ Reg 85703, 28 Nov 1950. Meeting participants included L. M. Biberman, S. R. Crockett, W. D. Drinkwater, A. C. Ellings, Dr. R. S. Estey, W. P. Farris, F. M. Fulton, L. T. Jagiello, Dr. W. B. McLean, H. Meneghelli, H. H. Patton, Dr. P. Rolf, W. F. Sapp, G. C. Throner, and Dr. H. A. Wilcox.

Chapter 5

1. NAF scrapbook.

2. Thompson, S-52, 50–51.

3. *Rocketeer,* 9 Feb 1949, 1.

4. S-211, 23.

5. Ellis, S-203, 37–38; *Rocketeer,* 16 Feb 1949, 1, 8.

6. "A sad story, but the JRB was not designed to fight icing conditions," said Captain Thomas F. Pollock in review comments. The NAF scrapbook cites DeZan and Yearick as having been the first to locate the crash site, as does the *Rocketeer,* 27 Apr 1949, 1.

7. *Rocketeer,* 27 Apr 1949, 1, 7.

8. Paper, NP45-12, 16 Mar 1950, "Notes on Policy, Organization and Planning—NOTS," by Thompson for Secretary of Defense Management Committee, R&D Survey Task Force, 12–13 (TPR).

9. The group, led by Clarence B. Nickerson, included Robert N. Anthony, C. Roland Christensen, John G. McLean, and George Albert Smith, Jr. McLean already knew something about NOTS, since he was the brother of Dr. William B. McLean.

10. Research Board minutes, 8 Aug 1949, 1.

11. Paper NP45-12, 16 Mar 1950, 11; Thompson, "Remarks on the Organization and Operation of NOTS, 1945–1951," Senior Personnel Conference, NOTS, 7 Aug 1951, 27.

12. Clarence B. Nickerson, et al., *A Study of Administrative Problems at U.S. Naval Ordnance Test Station Inyokern, California,* Summer, 1949, 4 (subsequently referred to as Nickerson Report).

13. Nickerson Report, 12–24.

14. Paper, "Summary of Comments on Harvard Report by N.O.T.S. Personnel," prepared by Dr. Hugh Hunter, summer 1949 (McLPR).

15. Ltr, 14 Jan 1950, Thompson to Dr. R. W. Cairns, Assistant Director for Research, Hercules Powder Co. Schindler was familiar with the special needs of the Navy laboratory; during his 1943–45 tour as officer-in-charge of the Naval Ordnance Laboratory, he had set the wheels in motion for construction of NOL's permanent facility at White Oak.

16. Ltr report, 27 Feb 1950, NOTS Advisory Board to Commander, NOL, and Commander, NOTS, 2 (TPR).

17. NWCV2, 336–338.

18. In *Dahlgren* (McCollum, ed.), 74–75, Sawyer said that in 1946 he was "all packed and set to leave" for a job in Inyokern, but instead accepted an invitation from the Chief of BuOrd to serve as technical director of the first atom bomb test on Bikini Atoll.

19. Thompson, "Remarks on the Organization and Operation of NOTS, 1945–1951," 24.

20. Memo NP45/A3-1(R/LTET/lap) Serial (2500), 1 Oct 1948, "Establishment of Advisory Board for the Naval Ordnance Test Station," W. G. Switzer, Commanding, to Chief, BuOrd (McLPR). The list proposed C. C. Lauritsen, R. A. Sawyer, and R. H. Kent for 3-year memberships; R. B. and W. R. Brode, J. C. Hunsaker or E. L. Cochrane for 2-year memberships; M. J. Kelly and Bradley Dewey for 1- or 2-year memberships; L.M.K. Boelter for a 1-year membership; and H. P. Robertson for an unstated term. Other names suggested were D. B. Keyes, J. A. Hutcheson, W. H. Rodebush, and R. W. Cairns.

21. Informal memo, (A)-AGN:jc, 11 Dec 1948, A. G. Noble, "Memorandum for: B" (McLPR).

22. Ltr, NP45-12/QB, 22 Mar 1949, Switzer to Lauritsen (McLPR).

23. Lauritsen's pivotal role in the establishment and wartime rocket work of the station is described in detail in NWCV1.

24. Advisory Board minutes, 22 Aug 1949, 12.

25. Thompson made similar statements about the importance of E&F funding in four interviews (S-5, 106; S-15, 39; S-21, 67–69; and S-52, 50), as well as in several speeches.

26. S-177, 3–4. Admiral Thomas H. Moorer, who was the station's experimental officer in December 1950–July 1952, just before and during the time when funding first became officially available for development of the Sidewinder missile, recalled in S-208, 17, that the Caltech money allowed work to proceed despite official opposition to the project.

27. Draft paper, 173/RWB:lrc Reg 735, no date, "Narrative Summary of History and Policies Concerning Methods of Financing Exploratory and Foundational Research Effort at NOTS," Encl. 3 to Research Board minutes, 22 Jun 1954, 1–2.

28. Encl., "N.O.T.S. Advisory Board Meeting October 10–14, 1949. Discussion on the subject: Relations between the Bureau of Ordnance and N.O.T.S.," in undated Lauritsen ltr written between 10 and 28 Oct 1949, to Commander, NOTS (Advisory Board files).

29. Ltr, 23 Nov 1949, Ralph A. Sawyer, Dean, Horace H. Rackham School of Graduate Studies, University of Michigan, to Thompson (TPR).

30. Memo, 27 Feb 1950, "Continuity of Support for NOTS and NOL," R. W. Cairns, acting chairman of the Joint Advisory Boards, to Commander, NOL, and Commander, NOTS (TPR). The memorandum cited Re's minimum appropriations as \$3.6 million to NOL and \$4.3 million to NOTS. According to a draft memo (Memo 173/RWB:lrc Reg 735, 2) appended to the Research Board minutes of 22 June 1954, the first increment of Re's support, an allotment of \$500,000 for obligation during fiscal 1950, was sent to NOTS in December 1949, along with the proviso that the funds were to be used at the station's discretion "for financing the cost of exploratory and foundational scientific investigation relating to matters of concern to ordnance problems and/or ordnance equipment."

31. Booz, Allen R&D management study, 134, notes that the term "foundational" was selected to avoid conflict with the Office of Naval Research over ONR's exclusive control of basic research. The study also explains (142) the transition of these funds to the later IR&IED funding: the independent exploratory development category emerged as a second discretionary fund in 1959, and the foundational research category was renamed independent research in 1964.

32. Draft memo, 173/RWB:lrc Reg 735, 3.

33. Memo Op-83/LMR Ser 162PO8, 21 Apr 1952, Naval Inspector General to Chief, BuOrd; Chief, BuAer; CNO; et al. Encl. 1, copy of rough draft of report, 15 (TPR).

34. McLean later told a House of Representatives oversight committee, "I believe that one of the most important functions of the laboratory director is to apply [discretionary funds] in such a way as to investigate new ideas of the laboratory personnel. The ability to act quickly on new suggestions is very important in maintaining the morale of scientific people." *News and Views*, May 1968, "Bill McLean on Laboratory Management" (testimony of McLean on 27 Mar 1968 before the House Subcommittee on Scientific Research and Development), 9.

35. Barrett Tillman, "In Harm's Way: The Saga of Gambier Bay," *The Hook, Journal of Carrier Aviation* (Winter 1986) 50–51.

36. The Naval Air Missile Test Center was commissioned as an operating entity on 1 October 1946. Commander (later Captain) Grayson Merrill, who became Point Mugu's first technical director (1946–49), predicted that "this site will meet the Navy's needs 25 years hence," an understatement as it turned out, since work at Point Mugu has continued under the Naval Air Warfare Center Weapons Division (the same Naval Air Systems Command organization that includes China Lake). See White, *Interpretive History of the Pacific Missile Test Center*, for an overview of the organization's history.

37. Vieweg's enthusiasm for China Lake was so strong that his successor, Stroop, recalled that upon his own sudden reassignment from NOTS, "Bowser heard about it, and he called me up and wanted to know if I couldn't arrange to get him recalled to active duty. He'd like to come back and serve at China Lake!" Stroop, S-191, 60.

38. Research Board minutes, 3 Oct 1949, 2–3.

39. Memo RD&TO Dir's Ofc (LTET/lap) No. 1005-8, 1.

40. Memo Ser 200-321, "Civil Service Examining Policy With Reference to Professional Scientific and Engineering Positions," Director, U.S. Navy Electronics Laboratory, San Diego, to Secretary of the Navy, enclosed in 20 Sep 1949, ltr, Director, NEL, to NOTS.

41. Ltr, 26 Aug 1949, W. R. Brode to Thompson (TPR); memo, NP-36 (Ad2)HDL:ab, 7 Oct 1949, "Junior Scientist and Engineer Examination Announcement Proposed by the Civil Service Commission," Chief, BuOrd, to Under Secretary of the Navy, Office of Industrial Relations; ltr OTR 290:jem, 16 Dec 1949, Acting Chief, Office of Industrial Relations to U.S. Civil Service Commission.

42. Ltr, K.T.NAS:tp, 5 Jan 1950, Executive Director, U.S. Civil Service Commission, to Office of Industrial Relations, Dept. of the Navy; the NOTS routing cover sheet to this letter contains Vieweg's note.

43. "AOD Christmas film, 1953," presented by Division 4, producer J. C. Keyes; director John Boyle; writer Jim McLane (collection of Photo/Video Branch, NAWCWPNS, China Lake). The name "J.P." was meaningful to the audience, since those letters designated a junior professional, a recently graduated scientist or engineer assigned to a first-year training program.

44. Crawford, S-171, 74–75. These two buildings on Blandy Street were subsequently used as offices for the Personnel Department and the Housing Office, then torn down in the 1980s when the site was converted to a park.

45. Crawford, S-171, 75–76. These modest amenities were augmented in late 1950 at the instigation of the China Lake Community Council, when telephones were installed in all 18 of the station's dormitories (*Rocketeer*, 22 Nov 1950, 1).

46. Undated flyer NP45-652/PL-30/JAN, "Employment Opportunities," NOTS, Inyokern, California." Emphasis in the original.

47. Paper, "Information Prepared for the Management Committee Task Force of Research and Development, Office of the Secretary of Defense," NOTS, 12 Apr 1950, 55.

48. *Rocketeer*, 14 Sep 1956, 1. The first FHA financing came to the Indian Wells Valley in 1952 in the form of two inexpensive housing projects (discussed in Chapter 14). Further FHA financing was not available until after the 1956 passage of Public Law 574 by the 84th Congress cleared the way for the Department of Defense to guarantee FHA against potential mortgage insurance loss. Financing with FHA backing became generally available only after the Secretary of the Navy affirmed the permanence of the Naval Weapons Center in 1968 (Paper, "Statement of Permanency Naval Weapons Center, China Lake, California," signed by Paul R. Ignatius, Secretary of the Navy, 28 Aug 1968).

49. *Rocketeer*, 24 Jan 1951, 1. Plain, whose distinguished 1945–76 career at NOTS included heading the Physics Division and the Mathematics Division and serving as associate head of the Research Department, died in November 1997, but as of this writing his widow still owns Plain Acres.

50. McClung, S-188, 83–84.

51. *Rocketeer*, 15 Feb 1950, 1. These houses, called Normac Duplexes, were on Randolph, Ringgold, Rodman, Rowe, and Radford Streets.

52. S-206, 12 Mar 1992, 22.

53. *Rocketeer*, 3 May 1950, 1, 5.

54. *Rocketeer*, 6 Sep 1950, 1.

55. *Rocketeer*, 13 Dec 1950, 1; memo, NP45-20/N4-1 Ser 3849, 29 Sep 1950, "Rental Trailer Housing," Commander, NOTS, to Chief, Bureau of Yards and Docks via Commandant, 11ND, and Chief, BuOrd.

56. Fully a third of the approximately $27 million of Fiscal 1950 funds authorized by the Navy Shore Station Development Board for construction projects at NOTS was earmarked for family housing (memo, A1-1 ND11-07/Le Ser 117/07, 16 Aug 1949, "Shore Station Development Program—SUBMISSION OF," Senior Member, Local Shore Station Development Board, 11ND, to Distribution List); memo, NP45-1704/N4-1 Ser 3841, 29 Sep 1950, "Additional Trailer Housing, request for," Commander, NOTS, to Chief, BuOrd.

57. Naval SpeedLtr NP45-17/bw Ser 4606, 24 Nov 1950, "Trailer Housing, request for," Commander, NOTS, to Chief, BuOrd.

58. Memo NP45-1704/N4-1, 26 Dec 1950, "Additional 100 Trailers," Commander to Community Manager.

59. S-171, 76. Crawford noted in his review comments, "Having hired on in May 1950, I was always just ahead of the big hiring surge from the Korea buildup, so got a good choice of housing."

60. Circular ltr N4-1, R-432, CirLet #26-49, 30 Jun 1949, "Construction of Private Rental Housing for the Naval Establishment Under Title VIII of the National Housing Act," Chief, Bureau of Yards and Docks, to distribution list; *Rocketeer*, 31 Oct 1951, 1. The Wherry Bill was named for its sponsor, Senator Kenneth S. Wherry of Nebraska

61. Memo NP45-20/N4-1, 7 Mar 1950, "Title VIII Housing for U.S. Naval Ordnance Test Station," Community Manager to Commander; paper, "Information Prepared for Shore Establishment Survey Board, Office of the Naval Inspector General," NOTS, 15 Jun 1950, 43.

62. Continental Subdivisions, Inc., "Exclusive Sellers of Transcontinental Land and Water Co.'s Rocket Town," claimed in an undated flyer, "This new frontier of opportunity close to the amazing NOTS has *proved* successful due to the sensational response of the buying public!" Claiming with some justification that "Hundreds of workers are here NOW . . . eager for homes," and that "Expansion possibilities are unlimited for homes, shops, markets and business firms of all kinds," the flyer also touted the property's Bowman Road location, which would be sited along a "possible new transcontinental highway."

63. Ltr, NP45-20/N4-1/A1-1 Ser 3815, 26 Sep 1950, W.V.R. Vieweg, Commander, NOTS, to Mr. John E. McGovern, District Director, FHA, Los Angeles; ltr NP45-20/N4-1 Ser 3370, 23 Aug 1950, Commander, NOTS, to Mr. Wilbur H. Stark, Broker, Indian Wells Valley Realty Co., Ridgecrest.

64. Ltr, NP45-20/N4-1 Ser 3555, 7 Sep 1950, Commander, NOTS, to Mr. Clarence F. Ives, Inyokern.

65. *Rocketeer,* 24 Jan 1951, 1, 5.

66. Coletta, *The United States Navy and Defense Unification 1947–1953,* 331–332.

67. Committee on the National Security Organization, *Report to the Commission on Organization of the Executive Branch of the Government,* 15 Nov 1948, 14–15, 26–31 (RG38).

68. Coletta, 127–132.

69. Rearden, *History of the Office of the Secretary of Defense, Volume I, The Formative Years: 1947–1950,* 327.

70. Rearden, 50–55; Borklund, *Men of the Pentagon: From Forrestal to McNamara,* 70–71; Booz, Allen R&D management study, 24, 35.

71. King (Chapter 6), *National Security in the Nuclear Age,* Turner and Challener, eds., 147.

72. Coletta, 161.

73. Condit, *History of the Office of the Secretary of Defense, Volume II The Test of War: 1950–1953,* 2–5.

74. Borklund, 87.

75. Kolodziej, *The Uncommon Defense and Congress, 1945–1963,* 37, 108; Rearden, 521–522.

76. Paul H. Nitze, director of the State Department Policy Planning Staff, chaired the group; the chief DoD representatives were Major General Truman H. Landon (USAF); Major General James H. Burns (USA Ret.); Najeeb E. Halaby, director of the OSD Office of Foreign Military Affairs; and Robert LeBaron, chairman of the Military Liaison Committee. For a more detailed discussion of NSC 68, see Rearden, 521–536.

77. Condit, 6–10; Allard, "'Interservice Differences," 83.

78. See Chapter 12.

Chapter 6

1. Glatt, 5–6.

2. Highberg, S-121, 24–25. Highberg earned a Ph.D. in mathematics from Caltech in 1936, then taught or 12 years at Whitman College, Walla Walla, Washington, before hiring on at China Lake in July 1947. He began his NOTS career in the Math Section of the Research Department, moving the following year to the Ballistics Division as head of the Exterior Ballistics Section. He became head of the Ballistics Division in 1951, then head of the Test Department in 1955. He retired in 1975.

3. Knemeyer, S-200, 10. Knemeyer graduated from Caltech in 1944, and after a short stint at Douglas Aircraft in Long Beach, became an ordnance officer in the Navy, training

fleet pilots on the East Coast to fire the NOTS-developed Tiny Tim. After World War II he was involved in the search for a test range long enough to accommodate guided-missile tests. During that search (which culminated in establishing a range at White Sands Proving Ground), Knemeyer visited China Lake for the first time. After leaving the Navy and returning to Caltech for his master's degree in aeronautical engineering, he started work at China Lake in June 1948 and rose rapidly through a series of increasingly responsible positions, heading the Weapons Development Department and the Weapons Planning Group and serving as deputy technical director, strike systems. He was a notable proponent of the "smart buyer" concept and had cognizance over nearly all of China Lake's major products in the course of his 34-year career on the desert. A 1961 recipient of the L.T.E. Thompson Award, China Lake's highest honor, he also was honored with two Navy Meritorious Civilian Service Awards. After his 1982 retirement, he served as head of the Ridgecrest office of Comarco. See Appendix B for the Thompson Award citation.

4. Glatt, 7; Knemeyer, 20 Feb 1992; and Amlie, S-199, 67, among others. A native of Chicago, Haseltine received his Ph.D. in physics from MIT. During World War II, he was an officer in the Army Ordnance Department, specializing in fire control design and artillery procurement. He came to China Lake in 1946. In 1955 he became head of the Ballistics Division, also becoming the Research Department's senior research scientist in 1957. He retired in 1975 and died in 2005.

5. S-200, 9.

6. Ltr, 3 Jun 1953, Thompson to Stroop (TPR); McEwan review comments, 18 Aug 1998.

7. McEwan review comments.

8. Research Board minutes, 9 Feb 1953, 5. The *Statistics Manual*, first published by Dover Books in 1957, returned royalties to the U.S. Treasury for many years thereafter. A later edition of the book was still in print as of 2005.

9. *Rocketeer*, "12 Years of Progress," 8 Nov 1955, 15.

10. Leroy Riggs recalled in his review comments that the Ballistics Division was short of desks, so he and Peggy Rogers sat on opposite sides of a small gray conference table. "We kicked each other often," said Riggs.

11. Hunter, S-95, 11.

12. After Fred Rogers died in February 1956 at the age of 41, Peggy Rogers and her five young children returned to NOTS in 1957. During her subsequent brilliant 23-year career at China Lake, she was a crucial contributor to the station's work on free-fall weapons. In 1974 she became head of the Weapons Development Department, the first woman to head a technical department at China Lake and the first woman in the Navy to attain the public-law pay rank. By the time she retired in 1980, she had earned numerous awards, including that of the Federal Laboratories' Woman Manager of the Year. She died on 14 March 1989. Two subsequent generations of the Rogers family have also worked at China Lake.

13. Elvey became deputy head of the Research Department in 1948, acting as the department's manager until Dr. John Shenk was named department head in October 1949. After serving as head of the commander's staff, Elvey left NOTS in October 1951 to become director of the University of Alaska Geophysical Institute. In August 1951 Roach sailed to France for a yearlong Fulbright fellowship at the Institut d'Astrophysique in Paris. The Research Board, eager to keep Roach interested in station employment, promoted him in his absence, assigned him to the Research Department office as senior research scientist, and gave him a free hand to spend half of his time on "work of his own choosing." (Research Board minutes, 28 Jan 1952, 4.) Roach stayed only until June 1954, when he joined the Central Radio Propagation Laboratory of the National Bureau of Standards. He told attendees at his farewell luncheon that he was remorseful about leaving, but that, "the upper atmosphere program was expanding

beyond that which was appropriately handled at a Navy station at this time." (*Rocketeer*, 18 Jun 1954, 5.)

14. The long runways of Armitage Field were a legacy of Project Camel. According to Lieutenant General Leslie R. Groves, "I approved of Inyokern and the first thing they said was that they needed some runway extensions so that our B-29s could take off. I paid for the extensions from I think 8,000 feet to 10,000. I told . . . Parsons that I thought I was being blackmailed but that we might need the extensions." (Groves, S-42, 22–23).

15. Like many who came to the desert on short-term assignments, D'Ooge opted to stay at China Lake at the conclusion of the project. He joined the Research Department's Applied Science Division and later worked in the Propulsion Development Department, where he patented a number of ingenious devices, notably a thrust-termination device adopted universally in ballistic missiles to stop rocket action at a predetermined velocity (Bowen, S-175, 13).

16. As with other NOTS research projects, Apollo also appears to have supported more immediate applications. "The only mishap the group has run into occurred last year when one of the planes, on a scientific mission, was lost in Lake Meade. . . . No serious injuries were incurred," reported the *Rocketeer*, 3 Aug 1949, 7. According to *Smithsonian*, Oct 2005, 32, the aircraft's mission, secret at that time, was to test an experimental sensor unit called Sun Tracker that would allow missiles to navigate by the sun. The tracker was evidently a precursor to the systems that guide today's cruise missiles. A private dive team located the wreck of the submerged B-29 170 feet below the surface of Lake Mead in 2001, and by 2005 the National Park Service Submerged Resources Center was preparing the site for visits by amateur divers.

17. Edward V. Ashburn, "The Naval Ordnance Test Station Program of Research on the Physics of the Upper Atmosphere," informal paper, circa 1961, 6–7; *Rocketeer*, 23 Aug 1949, 7.

18. Memo ONR:422:OL:im Ser 6417, 28 Mar 50, "Project APOLLO, Request for cancellation of," Chief of Naval Research to Chief of Staff, U.S. Air Forces.

19. Bertha M. Ryan, "50 years later—Navy role in Sierra Wave Project recalled," *News Review*, 12 June 2002, 5.

20. Ashburn informal paper, 9.

21. C. T. Elvey, Senior Research Scientist, "Light From Night Sky & Upper Air Research," *Rocketeer*, 13 Sep 1950, 3, 7; 20 Sep 1950, 3, 7; 18 Oct 1950, 3.

22. Ashburn informal paper, 8–11.

23. *Rocketeer*, 24 May 1950, 3; memo, ONR:Pasa/WNA:lw A19 Ser SC-1408, 26 May 1950, "China Lake Conference on the Upper Atmosphere," Commanding Officer, ONR, Pasadena, to Commander, NOTS.

24. Saint-Amand, S-120, 2–3. Saint-Amand began his employment at NOTS in 1950, when as a Caltech graduate student he worked part-time at the Pasadena Annex on night sky research. After obtaining his doctorate in geophysics and geology from Caltech in 1953, he came to NOTS in January 1954 to continue night-sky work in the Physics Division. After a Fulbright research grant at the Institut d'Astrophysique in Paris in 1954–55, he became head of the NOTS Physics Division's Optics Branch, where work expanded to include earthquake studies and gravitational observations. In June 1958 Saint-Amand took a leave of absence to work for the International Cooperation Agency, where he set up a new school of geology at the University of Chile. Back at NOTS in January 1961, he again headed his former branch, which expanded to become the Earth and Planetary Sciences Division. Saint-Amand is best known for pioneering weather-modification research and applications. After his 1981 retirement from China Lake, he served for many years on the Indian Wells Valley Water Board.

25. *Rocketeer*, 18 Aug 1948, 1, 5; 13 Sep 1950, 1, 7; 10 Oct 1951, 7.

26. *Rocketeer*, 13 Sep 1950, 7; Memo 44 NP36/N1-13 Ser 44/44, 22 Jan 1951, "White Mountain Test Facility, Naval Ordnance Test Station; use of by University of California,"

Commandant, 11ND, to Commander, NOTS; Ashburn informal paper, 7–8. Olson, "White Mountain Research Station: Institution of 'Highest' Learning," *Naval Research Reviews,* has an overview of scientific work at White Mountain under Berkeley's aegis.

27. Knemeyer review comments.

28. Ben Keller, "AOD Seeks To Do Impossible. Mojave Desert Ideal for Aircraft Ranges," *Rocketeer* special issue, 8 Nov 1955, 2.

29. NAVORD Report 1196, NOTS 252, *Aviation Ordnance Test Facilities,* 27, 31.

30. Notes for Ward talk to all-hands AOD meeting, 15 Mar 1960 (WPR).

31. Project Atlas, funded by the Manufacturing Division of BuOrd, was set up to train fleet squadrons in the theory and maintenance of the AN/ASB-1 system.

32. RM-3, 133–135.

33. OPNAV Report 5750-5, Chapter VII, *History of the U.S. Naval Ordnance Test Station China Lake, California August 1945—December 1958,* 7, 29; Informal Research Pkg #7.

34. William B. McLean, "The Sidewinder Missile Program," Chapter 15 in Kast and Rosenzweig, *Science, Technology, and Management,* McGraw Hill, 1962, 166.

35. S-211, 33–34.

36. S-202, 22–24.

37. Swift, who earned his Ph.D. in experimental physics from the University of Iowa, taught physics at the Universities of Iowa and New Mexico before arriving at NOTS in 1946. He worked on fire-control systems at China Lake until 1955, when he joined Santa Barbara Research Center, then North American Rockwell Corporation. He returned to China Lake in 1972–74 to serve as associate head of the Research Department.

38. "Aircraft Fire-Control System EX-16," *Rocket Quarterly,* Mar 1955, 17–23.

39. McLean, "Progress Report on the Technical Program," Senior Personnel Conference, 29 Jun 1955, 3.

40. Memo Op-83/LMR Ser 162PO8, 21 Apr 1952, "U.S. Naval Ordnance Test Station, Inyokern, China Lake, California; Industrial Survey Division Report No. 157," Naval Inspector General to Chief, BuOrd; Chief, BuAer; CNO; et al., Encl. 1, "cop(ies) of rough draft of report," 14.

41. Memo Op-83/LMR Ser 162PO8, 21 Apr 1952, 1.

42. Stroop Naval Institute oral history, 315 (OA). On the recommendation of the Franke Board, the two bureaus combined into the Bureau of Naval Weapons (BuWeps) in 1959, and Stroop moved from chief, BuOrd (1958–59), to became the first chief, BuWeps (1959–62).

43. Memo 01/WBM:nft, no date, "Report of Travel (Wm. B. McLean to Washington, DC, and The Hague, period 25 Apr–11 May 1954)."

44. "Ordnance. BuOrd's Guided Missile Program," *Naval Aviation Confidential Bulletin,* Jul 1948, 33 (OA).

45. Research Board minutes, 10 May 1948, 1.

46. Memo (Re2b)-ABD:eh, 4 Dec 1948, "Rocket Fuze Development Work at the Naval Ordnance Test Station, Inyokern," Chief, BuOrd, to Commander, NOTS

47. Patton, S-179, 2; Ellis, S-203, 16.

48. Paper, "*Summary of the Technical Program,*" NOTS, 21 Jan 1950, 2.

49. RM-3, 54.

50. Starnes 2.75-inch FFAR report, 105.

51. Booty, one of the first civilian employees to arrive at NOTS (early 1944), had previously worked for Cenco Scientific Company (an instrument manufacturer). NOTS managers appreciated his skill in pushing station-developed weapons through mass-production stages. He became acting head of Design and Production in December 1950 and achieved full department-head status in July 1951. Later the same year, he became chief production engineer

on the staff of the technical director, a job he held until the Engineering Department moved from Pasadena to China Lake in 1954. He headed the Engineering Department until his 1965 retirement.

52. S-179, 87–89.

53. Memo RD&TO Expl Dept. Reg 35635, 27 Aug 1948, "Report of Proceedings. Symposium Concerning the U.S. Naval 2."75 Folding Fin Rocket at U.S. Naval Ordnance Test Station, Inyokern, California 18 and 19 August 1948," by W. E. Patrick, Jr., chairman; RM-3, 238.

54. Patton review comments.

55. Wiegand, S-111, 4.

56. Patton review comments.

57. Memo RD&TO Expl Dept. Reg 50960, 27 Sep 1948, "Production Engineering, 2."75 Folding Fin Air-to-Air Rocket," B. H. Sage to A. S. Gould and K. H. Robinson.

58. Memo NP45/F41-16(RX/IAS) Ser 0553, 19 Nov 1948, "Small Caliber Folding Fin Air-to-Air Rocket, Information on," CO, NOTS, to Chief, BuOrd; and response, memo, NP36(Re3)GTA:mv, 27 Dec 1948, Chief, BuOrd, to CO, NOTS.

59. S-179, 89–90.

60. S-197, 38.

61. Doig review comments, July 2005.

62. Wiegand review comments.

63. RM-3, 95–100.

64. NOTS 1459, 9; Wiegand review comments.

65. Memo NP45-55/P41-16(2) Serial 4384, 3 Nov 1950, "2."75 Rockets Manufactured by NOP, Forest Park," Commander, NOTS, to Commanding Officer, Naval Ordnance Plant, Forest Park, Illinois.

66. RM-3, 46–47, 107.

67. McEwan review comments.

68. Wiegand, S-111, 2–3.

69. Navy-NOTS 11ND, *Summary of Major Accomplishments.* 2–7.

70. NOTS 1459, 9.

71. Lt. Warren R. Hughes, USNR(R), "By the Rocket's Red Glare: Inyokern," *Naval Institute Proceedings*, Vol. No. 75, No. 11, Nov 1949, 1207.

Chapter 7

1. "Korean Proving Ground," *Naval Aviation Confidential Bulletin,* Nov 1951, 3 (OA).

2. Cagle and Manson, *The Sea War in Korea,* 26–29.

3. Cagle and Manson, 6–12.

4. Halperin in *American Defense Policy,* 191–192.

5. Gavin, *War and Peace in the Space Age,* 123–124; Martin Lichterman in *National Security in the Nuclear Age,* Turner and Richard D. Challener, eds., 43; and Borklund, *Men of the Pentagon,* 99; among others.

6. Kolodziej, 124–125; Allard, "An Era of Transition, 1945–1953," in *In Peace and War. Interpretations of American Naval History, 1775–1984,* Hagan, ed., 300–301.

7. Ltr, P14-2/LL of 13 Jul 1950, Harry T. Kranz, Regional Director, 12th U.S. Civil Service Region, San Francisco, to Commanding Officer, NOTS.

8. *Rocketeer,* 13 Sep 1950; 4 Oct 1950; and 14 Feb 1951, 1; memo, Op-83/LMR Ser 162 PO8, 21 Apr 1952, "U.S. Naval Ordnance Test Station, Inyokern, China Lake, California;

Industrial Survey Division Report No. 157," Naval Inspector General to Chief, BuOrd; Chief, BuAer; CNO; et al., 4 (TPR).

9. Memo NP45-65/RWA/bd Ser 3107, 4 Aug 1950, "Civilian Employees Holding Commissions in Reserves of Other Services," Commander, NOTS, to Chief, BuOrd.

10. Memo NP45-651/AJH/em Ser 4305, 27 Oct 1950, "Submission of information regarding mobilization assignments and requests for delays in call to active duty of reservists in key positions within the Naval establishment," Commander, NOTS, to Commandant, 11ND.

11. *Rocketeer,* 20 Jun 1951, 8.

12. Lakin, S-122, 18; see also similar recollections in Wertenberger, S-172, 12–13.

13. *Rocketeer,* 19 Jul 1950, 1; 10 Jan 1951, 1; 17 Jan 1951, 1; 14 Feb 1951, 1; and 18 Apr 1951, 1.

14. Thompson, "Remarks on the Organization and Operation of NOTS, 1945–1951," 38.

15. Field, *History of United States Naval Operations: Korea,* 62.

16. Cagle and Manson, 45–47; Hallion, *The Naval Air War in Korea,* 32–39.

17. Dr. Charles C. Lauritsen address, Weapon Exhibit Center Dedication, 4 Nov 1964, China Lake, 11; see Field, 197–198; Isenberg, *Shield of the Republic: The United States Navy in an Era of Cold War and Violent Peace, Vol. I, 1945–1962,* 191–205.

18. S-179, 4 Sep 1989, 50.

19. Hallion, 167; *Rocketeer,* 18 May 1957, 3.

20. The HPAG Rocket Motor" by Clarence Weinland, NOTS 2068, 40; *Rocketeer,* 18 May 1957, 3.

21. Memo NP45-4011/Reg 82197, 5 Sep 1950, "Trip Report, Combat Zone, Japan and Korea, 29 July 50 to 22 Aug 50," S. J. Marcus, to Deputy Head, Rockets and Explosives Dept., 3–4.

22. S-210, 63–64; similar quotation in S-179, 25–27.

23. RM-3, 69.

24. Draft paper, RD No. 3 (12-7-47; 12-13-47) 12-15-47, BHS/ELE/LS:lhm, "History of Rocket Program, NOTS," 7 (EPR).

25. Paper, "Summary of the Technical Program," NOTS, 21 Jan 1950, 2; Elton C. Fay, "Writer Tells Pilot's Story of Tank Hit," *Rocketeer,* 30 Aug 1950, 1, 5.

26. "The War on the Testing Ground," *LIFE Magazine,* 18 Sep 1950, 78.

27. Borklund, 97.

28. Ltr of appreciation, 090100-0346, NP36, 31 Aug 1950, Secretary of the Navy Francis P. Matthews to Captain W.V.R. Vieweg, Commander, NOTS (McLPR); Station Memo No. 72-50, NP45/12, 5 Aug 1950, "Work on Project Ram, Commendation for," Technical Director to department, division, and branch heads (TPR); Patton review comments.

29. Patton, S-179, 22.

30. S-233, 14–15. See also S-177, 21–22.

31. S-188, 4. In review comments, Ellis confirmed this memory and noted that his mother died on 25 July 1950.

32. L.T.E. Thompson speech at Senior Personnel Conference, 37.

33. S-188, 3, 6.

34. Crawford, S-171, 20.

35. Riggs, S-136, 42–43. Riggs was a 1948 graduate of the University of Texas in mathematics and physics. He came to China Lake that same year from the University of California at Berkeley, where he was a graduate student in statistics. Beginning at NOTS as a junior professional in the Ballistics Division, Research Department, he became head of the

Aeromechanics Division, Weapons Development Department, in 1961. He moved in 1968 to Corona to head the Missile Systems Department and to smooth the transition of that organization from the Naval Ordnance Laboratory to the Naval Weapons Center. He was head of the Electronic Systems Department in 1970–73 and acting technical director of the Naval Weapons Center from September 1973 to June 1974. Riggs, whose review comments and research suggestions contributed substantially to early phases of this book, died on 21 March 2004.

36. TM 379, *Exterior Ballistics of the 6."5 Anti-Tank Aircraft Rocket (ATAR), Part 1. Experimental,* by L. Riggs, 3, 7.

37. Riggs, S-136, 43–44.

38. Ellis, S-77, 57.

39. S-177, 21–22.

40. S-112, 47.

41. She also said that the other wives rallied around to make her feel at home. Jane Wilson, S-197, 44.

42. S-177, 21.

43. S-188, 8.

44. Riggs, S-136, 46; TM 379, 3–4.

45. This instruction manual, NAVORD Report No. 1243, was the product of a team of technical information specialists coordinated by Donald R. Kennedy. With direct orders from Levering Smith to document the ATAR project as it was being created, Kennedy discovered several areas where safety concerns dictated changed procedures or warning notices. In such instances, he recalled, "Cdr. Smith would have the writer go to those responsible to work out a better approach. Although I was only a GS-9 Scientific Staff Assistant (i.e. a nobody), Levering Smith's name was magic." Fax, 12 Oct 1993, Donald R. Kennedy, D. R. Kennedy & Associates Inc., Los Altos, CA, to Jill Guinn, NAWCWPNDIV.

46. Memo NP45-4011/ Reg 82197, 5 Sep 1950, "Trip Report, Combat Zone, Japan and Korea, 29 July 50 to 22 Aug 50," S. J. Marcus to Deputy Head, Rockets and Explosives Dept., 3–4.

47. Memo NP45-3085, 18 Sep 1950, "Report of Trip to Japan and Forward Areas; Submission of," G. C. Throner and Lieutenant Commander Richard Brown, USN, to Commander, NOTS.

48. Memo CHW:rjd A3-2(12)C 07164, 31 Aug 1950, "Report on Use of ATAR by VMF-214 in Korea," and Encl. 2, "Report on ATAR," Major Claude H. Welch, Marine Service Squadron 12, to Commander, NOTS.

49. Hallion, 40–47.

50. Admiral Thomas H. Moorer recalled in S-208, 6, that as a result the Experimental Office worked up a publication "giving "the most optimal selection of bombs and rockets and guns for different types of targets." The publication was used in the Korean War.

51. Throner and Brown memo NP45-3085; Welch memo CHW:rjd A3-2(12)C 07164.

52. Throner and Brown memo NP45-3085.

53. NAVORD Report 1243, NOTS 305, *6.50-Inch Anti-Tank Aircraft Rocket (ATAR) Description and Instructions for Use,* by Rockets and Explosives Dept., NOTS, 26 Jul 1950.

54. S-179, 24–25.

55. Fay, "Writer Tells Pilot's Story Of Tank Hit," *Rocketeer*, 30 Aug 1950, 1, 5; see also "The War on the Testing Ground," *LIFE Magazine*, 18 Sep 1950, 76–78.

56. Ltr, 090100-0346, NP36, 31 Aug 1950, Secretary of the Navy Francis P. Matthews to Vieweg (McLPR).

57. Station Memo No. 72-50, NP45/12, 5 Aug 1950, "Work on Project Ram, Commendation for," Technical Director to department, division, and branch heads (TPR).

58. William B. McLean paper, "The Art of Simple and Reliable Design," Spring 1963, 4.
59. Wilson, S-96, 5.
60. Hallion, 49.
61. Holmquist and Greenbaum, "Navy's 'In-House' Research Laboratories," *Naval Institute Proceedings*, 72.
62. Thompson, "Naval Ordnance Research," *Ordnance*, 4 (TPR).
63. "Navy Fights New Type War," *Naval Aviation Confidential Bulletin*, Apr 1951, 35–36 (OA).
64. Cagle and Manson, 230, quote the JCS Dictionary of Military Terms definition of "to interdict" as "to prevent or hinder, by any means, enemy use of an area or route."
65. Winton, *Air Power at Sea. 1945 to Today*, 42–45; Cagle and Manson, 241–243, 257.
66. Hallion, 148, 167.
67. Ltr, 21 Dec 1951, T. H. Moorer, NOTS, to L.T.E. Thompson, White Plains, New York; also memo, NP45-14, 6 Dec 1951, "Trip report," Experimental Officer to NOTS departments.
68. "Navy Fights New Type War," *Naval Aviation Confidential Bulletin*, Apr 1951, 36 (OA).
69. S-179, 13–15.
70. Century Publication Div., "Rocket Launcher Development Program," Engineering Report No. 604, Apr 1953, Century Engineers Inc. Burbank, CA, 1-1 to 1-11. Testing organizations included NOTS, the Naval Air Test Center, Patuxent River, Maryland; the Air Force Armament Center, Eglin Field, Florida; the Operational Development Force off the carrier *Leyte* (CV-32*)* in the Atlantic Ocean; and Marine Aircraft Wing 1.
71. Research Board minutes, 5 Jan 1953, 3.
72. Cairns and Lauritsen, "Report of Technical Field Service Sub-Committee," Advisory Board report, 4–6 Aug 1952.
73. Ltr, 8 Feb 1953, Cdr. F. A. Edwards, VC-35 DET M, CVG 9, FPO San Francisco, to Dr. N. E. Ward, NOTS, and annotated routing slip (WPR).
74. Handwritten ltr, 18 Feb 1953, Edwards to Ward (WPR). Capitalizations are in the original.
75. Ltr, 4 Mar 1953, Ward to Edwards (WPR).
76. J. D. Tikalsky, JOC, "Radar Raiders," *Aviation News*, Nov 1953, reprinted in *Rocketeer*, 4 Dec 1953, 6.
77. Ltr, 9 Apr 1953, Cdr. F. A. Edwards, VC-35 DET M, CVG 9, FPO San Francisco, to Dr. N. E. Ward, NOTS (WPR).
78. Cagle and Manson, 267; Navy-NOTS 11ND, *Summary of Major Accomplishments*, 1–33.
79. Cagle and Manson, 492.
80. Research Board minutes, 10 Nov 1952, 2.
81. Research Board minutes, 28 Sep 1953, 5.
82. Connolly remarks, "25th Anniversary Speeches," Center Theater, China Lake, 10 Nov 1968, 9.

Chapter 8

1. York and Greb, 19.
2. Neufeld, 37, 55–56, 66; Allison, "U.S. Navy Research and Development since World War II," 296–297. A concurrent study by the Navy's Guided Missile Coordinating Committee reached the conclusion in April that the Navy's Sparrow, Meteor, Dove, Petrel, and Oriole, plus the Air Force's Falcon were the "missiles of immediate importance to the Navy" and "a

reasonable and satisfactory effort in the field." Encl. 1 to CNO memo, Op-551B/jtm Ser: 0047P551, 17 Jun 1950, CNO to distribution list, "Guided Missile Coordinating Committee; Report of," Guided Missile Coordinating Committee to Deputy CNO.

3. Naval SpeedLtr, Re2b-ONS:dp, 7 Feb 1951, Captain M. R. Kelley, Re2b, to Commander, NOTS, a message confirming "certain instructions concerning 'Sidewinder' which were issued by BuOrd in telephone conversation between Captain M. R. Kelley, BuOrd, and Captain W. R. Vieweg, Naval Ordnance Test Station, on 6 February 1951."

4. Moorer, S-208, 4. The highest-ranking of China Lake military alumni, Moorer was Chief of Naval Operations in 1967–70 and chairman of the Joint Chiefs of Staff in 1970–74.

5. Moran, an experienced pilot, first reported to NOTS in January 1950. He returned in July 1955; during his three-year assignment as senior experimental officer for air-to-air weapons, he convinced the station to develop the radar-homing missile system that became Shrike. In 1970, he returned for a third tour on the desert, this time for a two-year tour as commander of the Naval Weapons Center. His subsequent naval career culminated in 1972–75 service as director of research, development, test, and evaluation in the Office of Naval Operations.

6. Among the many Sidewinder pioneers who recounted this explanation for the study numbers were Moorer in S-208, 5; and Moran in interview by Dr. Ron Westrum, 14–15.

7. York and Greb, 19.

8. Condit, 474; Nichols, *The Road to Trinity*, 280–282.

9. Memo Op-512B/jek Ser 0022P51, 11 Mar 1952, "Navy Guided Missile Program," CNO to distribution list (OA).

10. Condit, 474.

11. Hutcheson was one of the Advisory Board's founding members. After serving from October 1949 to July 1950, he served another short term in 1952.

12. Naval SpeedLtr, Re2b-ONS:dp, 7 Feb 1951.

13. *Rocketeer*, 14 Feb 1951, 1; Research Board minutes, 19 Jan 1951, 2.

14. Ltr, LTET:mw, 7 Aug 1951, Thompson to Rear Admiral M. F. Schoeffel, USN, Chief, BuOrd (TPR).

15. BA-1-75, 4 (NL).

16. *The Road to Trinity*, 287. Vice Admiral Edwin B. Hooper, who at that time was BuOrd assistant for nuclear applications, remembered that Nichols himself also had reservations about the Sidewinder program. "I never could quite understand why he was so opposed to this development," Hooper said in his Naval Institute oral history, 270 (OA).

17. Ltr, 7 Aug 1951, to RAdm. M. F. Schoeffel, USN.

18. NOTS TM 1782, 6; Wilcox ms, SW-2, 5 Nov 1986, 2.

19. Memo NP45-35 Ser 0535, 7 May 1951, "Procurement for Confirmation of Results of Feasibility Study 567," Commander, NOTS, to Chief, BuOrd; Rugg ms, 103–110.

20. NOTS TM 1653 (NVD 1269), *Status Report of Sidewinder Program as of 1 August 1953*, by Wilcox and Christman, 20.

21. Rugg ms, 99.

22. NOTS TM 1782, 6. According to Jack Crawford (in S-171, 20), the name OMAR referred to the "moving finger" of Omar Khayyam, with the moving finger symbolizing the beam the missile followed to its target.

23. Memo Re9a-MHS:hl S78-1(126) Ser. 006866, 31 Oct 1952, "Project OMAR; revised status report and planning of," Chief, BuOrd, to CNO (Op-51); Rugg manuscript, 121–122.

24. Woodworth, S-215, 18.

25. S-188, 13.

26. Rugg ms, 111, 113–117.

27. Undated draft memo, "Progress and Status of SIDEWINDER," 3–5, annotated by Wilcox and McLean and attached to office memo, 20 Jul 1952, Lt C to Howie. Although events proceeded so rapidly that this memo never needed to be sent, Wilcox later added an illuminating annotation for the benefit of Lieutenant (later Rear Admiral) Thomas J. Christman, who had been assigned the task of documenting Sidewinder's history: "The philosophy expressed is extremely good and should be included in a speed letter to the Bureau, perhaps. Please file somewhere." (CPPR).

28. *Rocketeer*, 1 Aug 1951, 6.

29. Memo NP45-14, 8 Oct 1951, "Current Status of the attitude of the Guided Missile Committee of the Research and Development Board regarding Fax Sugar 567 and OMAR," Experimental Officer to Technical Director; NOTS AdPub 112, *An Investigation of the Management of Research and Development Projects,* by Theodore Franklin Gautschi, Central Staff, NOTS, Aug 1962, 111.

30. Marvin and Weyl, "The Summer Study," *Naval Research Reviews,* Aug 1966, 2, 26.

31. McLean stated these opinions in an undated post-1953 document, which appears to be a deposition relating to GT&R's potential patent infringement of the Sidewinder seeker. Sidewinder and AN/DAN-3 were among the eight BuAer and BuOrd infrared-seeker projects briefly described in RDB Digest Series No. 41, LIR 45/2, *Review of the Field of Infrared Homing Devices for Missile Guidance,* prepared by Panel on Infrared of the Committee on Electronics, 15 Aug 1950, 18–19 (*RG38*).

32. Memo NP45-35 Ser 275, WBM:lmm, 1 Oct 1951, "Background on Development of DAN-3," Head, AOD, to Commander.

33. Ltr, CHT/nlp, 27 Jan 1992, Charles H. Townes, Dept. of Physics, University of California Berkeley, to Prof. Ron Westrum, Eastern Michigan University, Ypsilanti, Michigan. Townes was a member of the Project Metcalf team.

34. Memo NP45-14, 8 Oct 1951.

35. Office memo, 20 Jul 1952, Lt C to Howie; AdPub 112, 111; informal paper, "Comments and recollections by Lucien M. Biberman, 11 Aug 52, Seeker Models Used in Sidewinder Missile Development," 2.

36. Memo Re9a-ECS:gs Ser 29828, 28 Nov 1951, "Cognizance of Projects OMAR and SIDEWINDER in the Bureau of Ordnance; information on," Chief, BuOrd, to Commander, NOTS; BuOrd internal memo, Rexm:EMB:drb, 9 Nov 1951, "Projects OMAR and SIDEWINDER Transfer of Branch Cognizance of," Rexa to Re9, Re2, Re8.

37. Naval SpeedLtr, Rexm-MTH:drb, 28 Nov 1951, Chief, BuOrd, to Commander, NOTS.

38. Although the work was dangerous, careful safety procedures and luck prevailed—with one very public exception. On 10 July 1952, in the first fatal test-flight accident out of Armitage Field since August 1944, 200 members of the Aviation Writers Association watched Lieutenant Commander John E. Darden in an F2H-2 Banshee fire a salvo of 14 Mighty Mouse rockets at a ground target. His aircraft continued in a dive, smashing to earth in a huge ball of flame. Subsequent investigations determined that one of the Banshee's wings had snapped, possibly as the result of a thermal updraft as Darden crossed the taxiway. Darden, who had come to China Lake from the Navy General Line School at Monterey half a year earlier, had been the engineering officer at the Naval Air Facility and NOTS' primary Navy test pilot for the 2.75-inch FFAR. Just 30 years old at his death, he had been a Navy man since 1942. *Rocketeer*, 16 Jul 1952, 1; Ellis, S-203, 36.

39. Memo Rexa-BFM:w Ser 20103, 2 May 1951, Chief, BuOrd, to Commander, NOTS.

40. Memo Adz:CRB:jt, 13 Dec 1952, "Conference with Dr. Ellis concerning decentralization by BuOrd of rocket program," AD2A to AD2A files. "Bureau thinking should go in much

broader directions and leave to NOTS the determination of what sort of rocket will fit the requirements imposed," said Dr. Frederick W. Brown, the author of the ROPAC idea.

41. Research Board minutes, 21 Jan 1952, 4–5.

42. Memo NP45-55/P41-16(2) Ser 4384, 3 Nov 1950, "2."75 Rockets Manufactured by NOP, Forest Park," Commander, NOTS, to Commanding Officer, Naval Ordnance Plant, Forest Park, Illinois.

43. Research Board minutes, 19 Nov 1951, 3–4.

44. Trip report NP45-14, 6 Dec 1951, Experimental Officer to distribution list, 2–4.

45. Research Board minutes, 21 Jan 1952, 5; and 3 Mar 1952, 2.

46. According to Harold Patton (S-179, 3–4) Ellis devised the name Gimlet by inverting "MiG" under the rationale that the new missile would be anti-MiG, then added a diminutive because the rocket would be small. Ellis didn't remember that rationale for the name.

47. "2.0-Inch Folding-Fin Aircraft Rocket (Gimlet)," *Rocket Quarterly,* Jun 1954, 1–2; Patton review comments.

48. Recruiting brochure, Navy NOTS 11ND, ". . . Your Future Is Today's Business," NOTS, May 1956; Cozzens, S-126, 40.

49. S-179, 9–10.

50. *Rocket Quarterly,* Jun 1954, 3–6.

51. *Rocketeer,* 14 Aug 1953, 3; and 18 Mar 1955, 6.

52. *Rocket Quarterly,* Jun 1954, 11.

53. Century Publication Div., Engineering Report No. 604, *Rocket Launcher Development Program,* Apr 1953, Century Engineers Inc., Burbank, CA, 4-1 to 4-3.

54. Engineering Report No. 604, 3-3 to 3-5.

55. Steve Little review comments, Aug 1998. Heinemann, the celebrated designer of more than 20 aircraft, served on the NOTS Advisory Board in 1953–57 and as the board's chairman in 1957. "I am proud to be called a NOTS Maverick," Little said in a 30 Aug 1998 ltr to the author. By his 1974 retirement, Little was the deputy for engineering in the Program Management Division of China Lake's Surface Missiles Department. He added that the entire time he was at NOTS, he was a "weekend warrior" at NAS Los Alamitos, eventually becoming executive officer of his squadron.

56. Marvin Miles, "Navy's Sidewinder Missile Downs Fighter in First Demonstration," *Los Angeles Times,* 4 Mar 1957, 21; Rocketeer, 26 Jul 1957, 4; Little review comments.

57. NOTS 989, *GIMLET 2.0-Inch Folding-Fin Aircraft Rocket.*

58. RM-3, 62–64.

59. RM-3, 65–70; memo, NP45-40 Reg 400099 JHW:mk, 17 Mar 1952, "Report of NOTS Advisory Board Meeting 8, 9 and 10 November 1951," Head, Rocket Dept., to Technical Director; Navy NOTS 11ND, *Summary of Major Accomplishments,* 1–6.

60. Patton review comments; "ZUNI Development Another Example of Teamwork Here," *Rocketeer,* 18 May 1957, 3.

61. James H. Wilson and Hugh D. Woodier, "The 5.0-Inch High-Performance Air-to-Ground Rocket (HPAG)," *Rocket Quarterly,* Mar 1955, 10.

62. NOTS 2068, 41.

63. Bernard Smith, *Looking Ahead From Way Back,* 1999, 47.

64. RM-3, 82–83.

65. Draft memo, NP45-15, revised by Research Board 6 Mar 1952, "Projects Proposed to be Dropped by the Bureau of Ordnance; Comments on," Commander, NOTS to Chief, BuOrd, 4; memo, NP45-40 Reg 400067 ELE:mk, 5 Mar 1952, "Comments on draft of BuOrd letter regarding deemphasis of certain aspects of NOTS program," Head, Rocket Dept., to Associate Director for Research & Development (WPR).

66. Wiegand review comments. See also "Spin Stability of Rockets Like Weapon A," *Rocket Quarterly*, Dec 1955, 16–20.
67. McLean, "Progress Report on the Technical Program," 4.
68. These numbers are cited in Neufeld, 43.
69. S-177, 25–26. An alternate spelling, Taifun, is given in NAVORD Report 2059.
70. After more than a decade of commuting between Pasadena and China Lake, one of the three, Dr. Hans Haussmann, moved in the early 1960s to China Lake, where he continued his successful NOTS career as a chemist. Another, Dr. Wolfgang C. Noeggerath, was a well-regarded thermodynamics consultant to the Underwater Ordnance Department until 1954, when he left NOTS for private industry. Levering Smith discusses the Paperclip scientists in S-177, 26.
71. NAVORD Report 2059, NOTS 754, *For Pilots Only: Pilots' Handbook of Rocketry*, 14.
72. Paper, Expl Dept. (6001) Reg 75077, 11 Nov 1949, 17; Research Board minutes, 6 Mar 1950, 2; S-177, 27.
73. H. W. Kruse and A. G. Whittaker, "Basic Research on Liquid-Propellant Systems," *Rocket Quarterly*, Jun and Sep 1956, 8–11.
74. Patton, S-179, 4 Sep 1989, 42.
75. RM-6, *Development of the 5.0-Inch Liquid Propellant Aircraft Rocket (LAR) Model 502,* 3.
76. RM-3, 114.
77. RM-6, 3.
78. Kolodziej, 153–162.
79. Memo NP45-40 Reg 400067 ELE:mk, 5 Mar 1952.
80. Memo NP45-15743/ASG/hp Ser 5145-52, 5 Mar 1952, "Reduction of Workload," Consultant for Rockets to Head of Staff.
81. The LAR propellant system also appeared in Diamondback, a short-lived nuclear application of Sidewinder pursued in 1956–57.
82. RM-3, 101.
83. NOTS 1459, 9–11.
84. Wiegand, S-111, 3.
85. *Looking Ahead From Way Back*, 47.
86. RM-3, 84–89; NOTS 872, *Rocket Department Technical Appraisal*, 95–97; Navy NOTS 11ND, *Summary of Major Accomplishments*, 1–31.
87. "Demolition Line Charge," NWC TP 6413, Part 1, *Major Accomplishments of the Naval Weapons Center and Its Predecessor Organizations*, 1980, 13–15.

Chapter 9

1. Vieweg, "Testing Naval Ordnance. Task of the Research and Development Center at Inyokern," *Ordnance*, 71.
2. S-188, 35–36.
3. Herman, "Metric Photography," *Rocketeer*, 8 Nov 1950, 3; Silberberg discussion with the author, 3 Jan 2005; John Di Pol review comments, 14 Apr 2005. Silberberg arrived at NOTS in May 1945, starting as a 76-cent-an-hour general helper. By the end of the war, he was making $26 an hour, a salary that allowed him to marry and move with his new wife, Patricia, into a storage closet, the only housing then available. During his subsequent 35-year career at China Lake, Silberberg contributed numerous improvements to range instrumentation, notably shuttered video camera technology funded by $2,000 in independent exploratory development money. That technology is used around the world today for such applications as slow-motion replays. "George epitomized the China Lake tradition of finding innovative solutions to highly

technical and complex problems in test data acquisition and processing," said Di Pol. "He was not in the headlines of glamorous and exotic projects, but in the background providing answers that were critical to the researchers and project engineers." In recognition of his special talents, Silberberg received the William B. McLean Award.

4. Marie McArtor discussion with the author, Feb 2006; *Daily Independent*, 6 Mar 1991, B1.

5. Dick Boyd, who was working at Area R when many of the Superfortresses were set up there, recalled that a group of 52 arrived directly from overseas. Boyd review comments, Sep 1988.

6. Gerrard-Gough, informal manuscript, "Super-forts at China Lake," Jan 1978; Di Pol in S-195, 53. During his 31-year career at China Lake, Di Pol served as associate head of both the Test Department and the Systems Development Department, and head of the Range Department. He became a Michelson Laboratories Fellow in Management in 1970, received the L.T.E. Thompson Award in 1975, and received the Navy's Distinguished Civilian Service Award at the time of his 1981 retirement.

7. Ward, S-195, 54. Bill Ward, Newt's brother, arrived in 1947 and stayed for a 26-year career at China Lake.

8. China Lake department heads meeting minutes, 19 Jun 1956, 1.

9. Research Board minutes, 27 Nov 1956, 1; Di Pol, S-195, 54. Testing had destroyed nearly all of the B-29s by the early 1970s. Aircraft museums vied to obtain the last few nearly intact B-29s. By the early 21st century, just one B-29 in the world was in flyable condition. "Fifi," owned by the Confederate Air Force (renamed Commemorative Air Force in 2004), was an alumna of the China Lake ranges, one of the few aircraft NOTS' tests had missed. A second ancient B-29, "Doc," owned by aircraft buff Tony Mazzolini, involved dozens of local volunteers in towing the Superfortress from China Lake ranges to Inyokern Airport in 1998. In 2000 Mazzolini trucked "Doc" to the Boeing plant in Wichita, Kansas, where the aircraft had been built by McDonnell Aircraft Company in 1944. The Boeing Company contributed facilities and tools, with volunteer aviation buffs doing the renovation work, but structural damage to the aircraft proved a daunting challenge. As of publication, "Doc" is not airworthy.

10. Memo NP45-3002 Ser 515, 31 May 1951, "Brief description of NOTS facilities under Test Department cognizance," Encl. 2, "Ground Ballistics Ranges G-1 and G-2 (Permanent)," Head, Test Dept., to Mr. Joseph E. Terry, BuOrd Rexd.

11. Bachinski, S-164, 9.

12. "Navy's Second Highest Civilian Award Presented Today to AOD's Duane Mack," *Rocketeer*, 18 May 1956, 5. Mack was one of a small group of Caltech employees accompanying Ellis in providing ground support for the first test conducted at NOTS in December 1943. Mack spent most of his career at China Lake as the head of range operations for AOD. He retired in 1972.

13. S-97, 7.

14. "We had a couple of people who stared at film so much that they almost ruined their eyes," Lakin recalled in S-122, 3. "In those days we had the most rudimentary calculators, which would add and subtract. We thought it was great when you could add, subtract, multiply, and divide on these mechanical calculators, which at that time cost about as much as our annual salary. If you had one of those you were really one of the elite." A graduate of the University of Chicago, Lakin arrived on the desert in 1946 fresh from service as a meteorological officer in the Army Air Forces. He spent his 35-year career at China Lake in the data assessment field and earned an L.T.E. Thompson Award in 1976 for his exceptional leadership in high-quality computer services. Lakin died on 9 June 2007.

15. Research Board minutes, 24 May 1948, 2.

16. Research Board minutes, 6 Jul 1949, 1–2; and 18 Jul 1949, 1–2.

17. *Rocketeer,* 5 Apr 1950, 3; and 31 Jul 1953, 6. The latter article consists of excerpts from a McEwan and Skolnik article in *Industrial and Engineering Chemistry.*
18. A. G. Hoyem, "Time-Saving Assessment Devices," *Rocketeer*, 11 Oct 1950, 3.
19. Smith, S-201, 8–9.
20. These facilities were established in 1945 (White Sands), 1946 (Point Mugu), and 1949 (Banana River, successively redesignated Cape Canaveral and Cape Kennedy). In 1958 these ranges, still under the direction of their respective services, became a triad of national ranges, with the Point Mugu facility redesignated the Pacific Missile Range, the Banana River facility redesignated the Atlantic Missile Range, and the White Sands Proving Ground becoming the White Sands Missile Range. In 1992 Point Mugu and China Lake became part of a single command, the Naval Air Warfare Center Weapons Division, under the Naval Air Systems Command.
21. Memo RW:hd (CEN1) 2525, 1 Apr 1955, Encl. 1, "Minutes of the Sixth Guided Missile Range Commanders Conference," Commander, U.S. Naval Air Missile Test Center, to CNO (OP-51) via Chief, BuAer (RG38).
22. Pacific Missile Test Center, *Days of Challenge Years of Change*, 41. The Range Commanders Council continues today, with two dozen ranges across the country participating, with the goal of sharing insights and products proactively within DoD.
23. Memo RW:hd (CEN1) 2525, 1 Apr 1955, Encl. 1. Di Pol, S-119, 3.
24. In 1956, in response to an Inspector General report criticizing the high overhead rates on the station's ranges, Navy Comptroller and BuOrd representatives concluded that NOTS' accounting practices were sound. The NOTS response was that "the modified industrial accounting used at NOTS should not be compromised to conform with other systems that provide less useful information." Memo Rex-2-JJr:jlm, 10 Mar 1956, "Recommendations of Panel to Examine the Missions and Tasks of the Naval Ordnance Test Station, China Lake, California; status of," Chief, BuOrd to Under Secretary of the Navy (Naval Inspector General).
25. S-106, 2–3. During World War II, Sewell served in the Army Air Forces, where he worked on guided missiles at Wright Field's Special Projects Laboratory. He earned bachelor's and master's degrees in physics from the University of California at Berkeley. He and his lab partner, Robert "Bob" Stirton then decided they had had enough of school. They applied to NOTS and both reported to work in the Ballistics Division on 23 Oct 1950. Both went on to outstanding careers at China Lake, with Stirton contributing numerous innovations in the computer science area. In 1954, Sewell moved into the warheads and explosives area, where he earned a worldwide reputation in detonation physics. He retired in 1986. He has occasionally been called on to serve as an expert witness, notably on the *Challenger* disaster.
26. NOTS TM 1782, 17, 29.
27. Memo NP45-3002 Ser 515, 31 May 1951, "Brief description of NOTS facilities under Test Department cognizance," Encl. 1, "Ground Ballistics Ranges G-1 and G-2 (Temporary)," Head, Test Dept., to Mr. Joseph E. Terry, BuOrd Rexd.
28. S-225, 5–6.
29. OPNAV Report 5750-5, Encl. 2, "Command History of the Marine Barracks, U.S. NOTS, 17 Jul 1945 through 31 Dec 1958," in Minor Research Package #12; *Rocketeer*, 17 Oct 1951, 3.
30. RM-3, 240.
31. NOTS TM 1782, 30–31.
32. A native of Canada, Toporeck had been in charge of an MIT contingent working on the pioneering Bat missile at the Bureau of Standards during World War II. He joined NOTS

in 1946 and became head of the Test Department in 1950. Those who worked with him remembered him as being a perfectionist, as hard on himself as he was on those around him. Useful insights into Toporeck's management style may be found in Wilson, S-96, 14–15.

33. Schoeffel Naval Institute oral history, 341–342 (OA). In S-88, 24, McLean discussed Toporeck's involvement.

34. Research Board minutes, 29 Dec 1952, 2–3.

35. Research Board minutes, 2 Feb 1953, 1, 4.

36. *Rocketeer*, 28 Jan 1953, 1.

37. Schirra was hand-picked to come to NOTS in 1952 by Moorer, who reported to NOTS management that "Schirra has had recent combat experience in Korea and has shown extreme interest in aviation ordnance as evidenced by several special reports which he forwarded to CNO while overseas." (Trip report NP45-14, 6 Dec 1951, Experimental Officer to distribution list.) In S-137, 2, Schirra said that he "worked directly with a fellow name of Tom Amen, a Navy lieutenant . . . who was a hotshot Navy flyer with Navy aircraft in Korea, and we had a great rapport going. So I was essentially working over that two-year period with what I called the four Toms (the others being Walker and Connolly)." Amen, who shot down the first Russian jet aircraft credited to a Navy flier during the Korean conflict, arrived at NOTS in July 1951 (*Rocketeer*, 18 Jul 1951, 1) and some years after he left NOTS in 1953 was killed in a Beechcraft crash.

38. Schirra and Billings, *Schirra's Space*, 35; similar reminiscences may be found Schirra's remarks during "A Salute to the Military," arranged by the Ridgecrest Chamber of Commerce and held on 5 Nov 1993 as one of the events of the China Lake 50th Anniversary celebration (S-234, 8).

39. Schoeffel Naval Institute oral history, 342–343 (OA).

40. "Views of Wally Schirra," *News and Views*, Mar–Apr 1969, 1.

41. Di Pol review comments; NWC TP 5564, *Major Test Facilities of the Naval Weapons Center*, 25 Mar 1974, 32.

42. Informal paper, RD&TO Expl Dept. Reg 35635, 27 Aug 1948, "Report of Proceedings. Symposium Concerning the U.S. Naval 2.'75 Folding Fin Rocket at U.S. Naval Ordnance Test Station, Inyokern, California 18 and 19 August 1948," by W. E. Patrick, Jr., chairman, 8.

43. Newkirk, "Aeroballistics Testing Facilities at the U.S. Naval Ordnance Test Station, Inyokern"; brochure, NOTS 1938, *NOTS Supersonic Tracks*, 15.

44. A. W. Nelson, "Rocket-Accelerated Launching Techniques—Part 2. Rocket Component and Projectile Testing," *Rocketeer*, 28 Mar 1951, 6.

45. NOTS 1130, 6; Di Pol review comments.

46. RM-3, 263–264; Weals review comments, 25 Jul 1998.

47. Swenson, Grimwood, and Alexander, *This New Ocean. A History of Project Mercury*, 10.

48. Encl. 1, "SNORT History," to memo, 30023/HV:ct Ser 59, 12 Jan 1962, "History of the Design, Construction and Operation of SNORT," Head, Supersonic Track Div., to distribution, 1; Research Board meeting minutes, February 26, 1948," 1. Unless otherwise noted, all SNORT dates and funding figures cited herein come from this document, subsequently referred to as SNORT History.

49. Ad Hoc Group on Track-Type Testing Facilities, "Report on Track-Type Testing Facilities," John K. Northrop, chairman, RDB Committee on Ordnance, 5 Jul 1949, 2–3.

50. SNORT History, 2–3. The name used in official correspondence for several months thereafter was "Aerodynamic Ballistic Track (Project SNORT)," but the first part of the name rapidly disappeared from use.

51. Jennison's designs were later recognized by three separate awards from the James F. Lincoln Arc Welding Foundation.

52. *Rocketeer,* 16 May 1951, 6. Heilbron came to NOTS in 1947 after gaining valuable experience in design of hydraulic structures for the city of Pasadena, the Metropolitan Water District of Southern California, and the Los Angeles District of the Army Engineers.

53. C. H. Heilbron, NOTS, "The Track System of Project Snort," prepared for Symposium on High-Speed Test Tracks, Holloman Air Force Base, Feb 1954, 2–4.

54. Highberg, S-121, 6–7.

55. *Rocketeer,* 7 Sep 1949, 2.

56. Coletta, 165.

57. Memo, 15 Jun 1950, Chairman, OSD Management Committee, to Secretaries of the Army, Navy, Air Force; Chairman, RDB (*RG38*).

58. Memo NP45-17/bw Ser 3178, 9 Aug 1950, "Track-type Testing Facilities, Conference on," Commander, NOTS, to Commanding General, Edwards Air Force Base, Muroc, CA; memo, EMRE/reb, 22 Aug 1950, "Conference Concerning NOTS Proposed Tests on Edwards Air Force Base 10,000 Ft. Research Track," Brigadier General Albert Boyd, USAF, Commanding, to Commander, NOTS.

59. Memo, 13 Nov 1950, OSD Management Committee to Secretary of the Navy (RG38).

60. *Rocketeer,* 25 Oct 1950, 1.

61. NOTS 568, *Design and Production Department Operations Fiscal Year 1952,* Design and Production Dept., NOTS, 30 Sep 1952, 6.

62. Memo NP45-P5509/A1-2/SNORT, 26 Nov 1951, "SNORT Construction Bids, Analysis of," Head, SNORT Design Staff, to Head, Design and Production Dept.. Research Board minutes, 27 Nov 1951, 1–2; Research Board minutes, 20 Dec 1951, 5.

63. "Supersonic naval ordnance research track (SNORT)," *Rocket Quarterly.* Jun 1954, 18–24; Technical Progress Report TPR 16, NOTS 752, *The supersonic naval ordnance research track (SNORT),* by James P. Judin, Test Dept., NOTS, Sep 1953, iii–4; Heilbron, "The Track System of Project Snort," 4–6.

64. SNORT History, 11; TPR 16, NOTS 752, 5, 11–12; *Rocketeer,* 12 Feb 1954, 6. The powerful 11.75-inch Tiny Tim motor would be used to power numerous subsequent tests.

65. *Rocketeer,* 2 Apr 1954, 6.

66. Brochure, Navy NOTS 11ND, "Dedication of the Thompson Aeroballistics Laboratory, November Ninth, Nineteen Fifty-Six."

67. Highberg, S-121, 4.

68. *Rocketeer*, 9 Nov 1956, 5.

69. Jesse R. Watson, "The X-CZP-1 Ballistics Camera," *Rocketeer*, 21 Jun 1950, 3; RM-3, 270.

70. Ernest C. Barkofsky, "Instrumentation for Aeroballistics Photography," *Rocketeer*, 5 Jul 1950, 3.

71. *Rocketeer,* 14 May 1952, 6; 13 May 1953, 6; and 9 Nov 1956, 1.

72. Memo 752/CHE:mgc Ser 5812, 4 Oct 1955, "Naming of Thompson Aeroballistics Laboratory; proposal for," Commander, NOTS, to Commandant, 11ND. The bureau's endorsement was in a memo, Esla-EAR:jca A4-2, 2 Dec 1955, "U.S. Naval Ordnance Test Station, China Lake — Naming of Aeroballistics Laboratory 'The Thompson Aeroballistics Laboratory'; proposal for," Chief, BuOrd, to Chief of Naval Personnel; and the approval was in Pers-G11-CMK, 19 Mar 1956, "Naming of Thompson Aeroballistics Laboratory," Chief of Naval Personnel to Commander, NOTS.

73. The *Rocketeer*, 9 Nov 1956, 2, notes a good excuse for the absence of one member from the meeting: "Dr. William Shockley, Director, Shockley Semi-conductor Laboratory, will be unable to attend. Dr. Shockley is the recent recipient of the Nobel Prize in physics."

74. Younkin, S-183, 7–9.

75. Details of the towers' construction are in an undated four-page document, "Tallest Timber Towers Ever Constructed," apparently published by Summerbell Roof Structures, the company that preassembled the tower's structural components.

76. NOTS 1433, *Randsburg Wash Test Activities: A Facility for Ordnance Testing Under Simulated Tactical Conditions*, Mar 1956.

77. Memo S78-1(26) (Re2b)-ONS:ss Ser 4980, 1 Jan 1950, "Establishment of Gun Range for Testing VT Fuzes," Chief, BuOrd, to Commander, NOTS; *Rocketeer*, 29 Aug 1951, 6.

78. "Summary of Long-Distance Telephone Call," 2 Nov 1951, R. A. Appleton to R. G. Daniel, Naval Ordnance Laboratory. Appleton arrived in China Lake in 1944 as a Navy lieutenant commander. After World War II ended, he entered the civilian work force. After an accomplishment-filled 28-year career in China Lake's test and evaluation organization, he retired in 1972 and died in 1977.

79. *Rocketeer*, 10 Oct 1951, 5; 16 Jul 1952, 6; and 14 Mar 1958, B-3.

80. Harvey [*sic*] Tillitt, "New Data Processing Device Being Installed at Laboratory," *Rocketeer*, 11 Sep 1953, 1, 8.

81. *Rocketeer*, 25 Sep 1953, 6.

82. Tillitt, NAVORD Report 3509, NOTS 1138, 25. An excellent paper about this pioneering use of the computer is "Harley Tillitt and Computerized Library Searching," by Jim Segesta and Keith Reid-Green, *IEEE Annals of the History of Computing*, Jul–Sep 2002, 23–34.

83. *Rocketeer*, 7 May 1954, 6; 24 May 1957, 6.

84. Tillitt, NAVORD Report 3509, NOTS 1138, 23, 27.

85. OPNAV Report 5750-5, 14.

86. Wertenberger, S-172, 43–44.

87. Informal paper, "Significant Developments—Test Department," Nov 1957, 1–2. Herman, who arrived on the desert in 1945 after graduating from Kalamazoo College (L.T.E. Thompson's alma mater), conceived and organized the Data Automation Branch, where he led efforts that dramatically improved the station's ability to rapidly assess test data. He became head of the Test Department's Assessment Division, then left China Lake in 1959 to found Decision Control Corporation, which designed and manufactured a pioneering minicomputer, the architecture of which had a profound effect on many computers to follow.

88. Paper, "NODAC. The Naval Ordnance Data Automation Center," presentation by the Data Automation Branch to the Research Board, 28 Oct 1958.

89. Research Board minutes, 28 Oct 1958, 3.

90. Wertenberger, S-172, 16.

91. Bernard, S-189, 9–10. Bernard rose at China Lake to become head of the Propulsion Systems Division, Propulsion Development Department. He left NOTS in late 1963 to work for Lockheed. Barney Smith, who was then technical director of the Naval Weapons Laboratory, Dahlgren, Virginia, hired Bernard, who succeeded Smith as technical director at Dahlgren, 1973–75. Bernard was technical director of Naval Ordnance Laboratory, White Oak, Maryland, 1975–77. For the following 10 years, he was director of land warfare on the staff of the Under Secretary of Defense for Research, Development and Acquisition. He and his brother Carl later established a consulting company in Arlington, Virginia.

92. S-180, 69. After World War II Navy service, Boyle completed his degree at the University of Minnesota, then worked for Minneapolis-Honeywell for a year before reporting to work at NOTS in 1951. After working for several years on radar versions of Sidewinder, he turned his attention to the problem of radar signature reduction for small boats. In 1973 he transferred to the Naval Surface Warfare Center, Dahlgren, working there until his 1983 retirement.

Chapter 10

1. Research Board minutes, 1 Oct 1951, 4; *Rocketeer*, 3 Oct 1951, 1.

2. *Rocketeer*, 14 Nov 1951, 1; 21 Nov 1951, 1; and 21 Nov 1951, 1. Thompson noted in a 7 August 1951 ltr (LTET:mw) to BuOrd Chief Schoeffel, "Margaret has apparently recovered to a nearly normal health but is required to rest most of the time—indoors." (TPR).

3. Memo Op-83/LMR Ser 162PO8, 21 Apr 1952, Naval Inspector General to Chief, BuOrd; Chief, BuAer; CNO; et al. Encl. 1, copy of rough draft of report, 17 (TPR).

4. *Rocketeer*, 8 Mar 1950, 1; and 2 Apr 1952, 6.

5. Wilcox, S-103, 8.

6. *Biography/NWC Technical Directors*, "informal interview with Dr. Marguerite Rogers re Fred Brown," 13 Apr 1976.

7. Station Order No. 33-48, 16 Dec 1948, "Command, Staff and Departmental Organization of the Naval Ordnance Test Station, Inyokern, California," 2.

8. S-97, 23.

9. Research Board minutes, 15 Jun 1951, 4.

10. Nickerson, McLean, Christensen and Associates, *A Study of Administrative Problems at U.S. Naval Ordnance Test Station, Inyokern, Calif.* Summer, 1951, 1, 6–10. Emphasis in the original.

11. BuOrd Order No. 28-51, A-MFS:jc, NP36, NP51, 22 Jun 1951, "Status of Naval Ordnance Test Station, Inyokern, and Naval Ordnance Laboratory, White Oak."

12. Research Board minutes, 13 Nov 1951, 3.

13. Technical director's position description, circa 1951, 3–4.

14. S-196, 24–25.

15. The "Inyokern" part of the problem disappeared in 1955, when the Secretary of the Navy officially changed the station's name to "U.S. Naval Ordnance Test Station, China Lake, California." SECNAV NOTICE 5450, Op-213C Ser 316P21, 4 Feb 1955, "U.S. Naval Ordnance Test Station, Inyokern, China Lake, California; established status and redesignation of," Secretary of the Navy.

16. NWC Vol. 2, 320.

17. Research Board minutes, 8 Mar 1948, 2. This concept surfaced again more strongly during the 1970s, when Naval Weapons Center scientists used the term Michelson Laboratories as the name for the center's research activities.

18. S-15, 10.

19. Hardy, S-34, 13. Unfortunate connotations of the word "test" among potential recruits led the NOTS Education Committee to ask in June 1958 that the name change to "Naval Ordnance Technology Station," thus keeping the initials NOTS (memo, 01/WBM:nft Ser 3344, 6 Aug 1958, "Change of Station Name; recommendation for" Commander, NOTS, to Chief, BuOrd). Despite the commander's endorsement, that recommendation also got nowhere with BuOrd. Brown's opinions are reported in a transcript, "Senior Personnel Conference," 23 Apr 1953.

20. Thompson, S-15, 10–13.

21. Memo RD&TO Dir's Ofc (LTET/lap) No. 1005-8, 20 Sep 1948, "Urgent Requirements of the Naval Ordnance Test Station," L.T.E. Thompson to Rear Admiral L. Dreller, USN, Office of Industrial Survey, 2–3.

22. The new housing included so-called "motel units" for bachelor housing as well as two- and three-bedroom family quarters, referred to as "Pink Bricks," constructed in an area north and east of the a slight rise beyond the Officers Club. This area was sometimes referred to as Snob Hill because of its quarters for senior officers, civilian department heads, and other high-level civilian personnel. Memo Es3-HMD:cwm NP36, 7 Aug 1951, "U.S. Naval Ordnance

Test Station, Inyokern, Calif.; Designation as a critical Defense Area," Chief, BuOrd, to CNO; undated draft ltr, 1704/MFO:hm, circa 1952, "Background for official letter to Housing and Home Finance Agency, San Francisco."

23. *Rocketeer*, 10 Jan 1951, 1, 5. Within a year construction began of six additional dormitories, each a two-story quadrangle housing 84 persons (*Rocketeer*, 23 Jan 1952, 1).

24. *Rocketeer*, 5 Sep 1951, 1, 5.

25. Administrative Board minutes, afternoon session, 4 Feb 1952, 2–24; *Times-Herald*, Ridgecrest, 24 Jan 1952, 1. Ridgecrest's first FHA-financed homes, small two- and three-bedroom homes located in the central part of town, still offer affordable accommodations for retirees, single people, and young families.

26. Administrative Board minutes, 13 Oct 1952, 2.

27. Memo, "Progress Report—Federal operation of communities data on," Head, Central Staff, to Technical Director (in Administrative Board minutes of 14 Jul 1952).

28. Ltr, 3 Oct 1952, Connolly to Commander John J. Hyland, USN, Director of Tactical Test, Naval Air Test Center, Patuxent River, Maryland.

29. Schoeffel Naval Institute oral history, 332 (OA). Connolly later earned three stars and became deputy CNO for air.

30. S-191, 59–60. In 5 November 1998, review comments, William E. "Bill" Davis, who arrived at NOTS in March 1953 as officer in charge of the commissary store, verified that Stroop did indeed pass that message along. During a friendly "welcome aboard" meeting, Davis recalled, Stroop "advised me that the scientists and engineers were the vital element in the success of NOTS weapons for the fleet so their full support was exceedingly important; he could not replace them, but he could replace me. He said all this so tactfully that I was out of his office and into the hallway before the full impact hit me."

31. Isenberg, 276. The Stroop Naval Institute oral history is cited as the source for this anecdote.

32. Stroop, Naval Institute oral history, 253–256 (OA).

33. *Rocketeer*, 5 Nov 1952, 5.

34. Research Board minutes, 24 Oct 1952, 2.

35. Borklund, 133–136.

36. Coletta, 321–323; Hone, *Power and Change: The Administrative History of the Office of the Chief of Naval Operations 1946–1986*, 29–30; Booz, Allen R&D management study, 27.

37. In 1955 Quarles became Secretary of the Air Force; he became deputy secretary of defense in 1957 and held that post until his death in 1959. Quarles was succeeded as assistant secretary of defense for R&D first by Clifford C. Furnas (1955–57), then by Paul D. Foote (1957–58).

38. York and Greb, 20–21; Booz, Allen R&D management study, 29–30. When Newberry retired in 1957, the assistant secretary job was abolished, with its functions reassigned to the ASD/R&D, whose job was then redefined as assistant secretary of defense for research and engineering.

39. Memo 1704/HAR:sc, 7 Feb 1953, "Central Staff Comments," Head, Central Staff, to Members, Administrative Board, "Comments on Reference (a)," 1.

40. S-191, 16.

41. Research Board minutes, 9 Mar 1953, 3.

42. Administrative Board minutes, 18 May 1953, 2.

43. *Rocketeer*, 23 Oct 1953, 5.

44. *Rocketeer*, 23 Oct 1953, 1, 5; 4 Dec 1953, 1; 26 Feb 1954, 1; and 20 Aug 1954, 1.

45. Ltr, 10 Mar 1953, Capt. E. C. Stephan, Director, Legislative Div., Office of the Judge Advocate General, Navy Dept., to Harlan Hagen, Member of Congress.
46. S-214, 9.
47. Night ltr, 9 Jul 1953, Ridgecrest Chamber of Commerce to Senators Saltonstall, Byrd, Knowland, Kuchel; Congressman Harlan Hagen; Commandant, 11ND; U.S. Chamber of Commerce; AP Wire Service.
48. "Minutes of Special Meeting of the China Lake Community Council," 8 Jul 1953, 2.
49. Two-page untitled paper, 8 Jul 1953, possible draft for *Rocketeer* article.
50. Night ltr, 9 Jul 1953, Ridgecrest Chamber of Commerce.
51. Telegram, Clarence E. Wineland, President, China Lake Community Council, to Senators Saltonstall, Knowland, Kuchel; Congressman Hagen, Commandant, 11ND; Associated Press Wire Service, U.S. Chamber of Commerce; ltr, HH:ina, 17 Jul 1953, Harlan Hagen, MC, to Mr. Clarence Weinland, President, China Lake Community Council.
52. S-204, 38.
53. Ridgecrest Chamber of Commerce newsletter, 18 Jul 1953.
54. S-225, 52–53.
55. So popular was the "Swap Sheet" that its two originators established a hard-and-fast rule that nobody (including the publishers) could take advantage of the offered items before the Friday morning distribution. A tradition of early Friday trading activities sprung up, with hundreds of residents taking advantage of the opportunity to purchase the items they needed at low cost. The "Green Sheet," as it became known, flourished in China Lake until 1970, when it moved to Ridgecrest under new management. The "Swap Sheet" is still issued once a week. In S-225, 76–78, Polly Nicol recalls the publication's early days.
56. Flyer, "Special edition, China Lake Community Councilor: Your Community Council Reports," China Lake, 31 Jul 1953.
57. S-186, 16 Nov 1990, 16. Jackson, who was then a member of the Personnel Department's Training Branch, later became the first Ridgecrest resident to serve (1965–77) on the Kern County Board of Supervisors.
58. Ltr, 31 Jul 1953, Ridgecrest Chamber of Commerce to whom it may concern.
59. S-225, 52.
60. Amlie review comments, 7 Mar 1998.
61. Stroop, S-191, 10, 37.
62. *Rocketeer*, 7 Aug 1953, 1.
63. Ltr, 20 Jul 1953, Thompson, White Plains, New York, to Brown (TPR).
64. *Rocketeer*, 31 Jul 1953, 1. After two years at WSEG, Stroop served as BuOrd deputy chief, then as commanding officer of Taiwan Patrol Force before becoming the first chief of the Bureau of Naval Weapons (a merger of BuOrd and BuAer) in 1959. In 1962 he became commanding officer of Naval Air Force Pacific Fleet. He retired from a distinguished 39-year naval career in 1965 and died in San Diego in 1995.
65. Nearly 40 years later, when Stroop was interviewed for China Lake's oral-history program, he was still espousing that position. "The thing that really annoyed me, the reason I was detached, was because I was selected for flag rank, and it [NOTS] at that time was not a flag billet. However, a few years later, they did make it a flag billet. . . . I thought it should be a young admiral's billet and I'd like to have been the guy that had it," he said. S-191, 1.
66. *Rocketeer*, 4 Sep 1953, 1, 5.
67. Ltr, 19 Jun 1945, Dave Young, BuOrd, to Captain S. E. Burroughs, NOTS.
68. Biographical Information/NWC Commanding Officers #6.
69. "Commanding Officer Greets Station Personnel," *Rocketeer*, 2 Oct 1953, 1, 5.

Chapter 11

1. "Sidewinder Status Song" from *The Sidewinder Operetta* by Walter B. LaBerge, late 1953.
2. Summary of Long Distance Telephone Call, 26 Nov 1951, "Discussion with reference to financing Sidewinder and Omar," by F. W. Brown to Capt. Kelley, BuOrd (CwPPR); Trip report, NP45-14, 6 Dec 1951, Experimental Officer to NOTS departments.
3. S-196, 30.
4. Memo BOPOSO Serial #5, 19 Dec 1951, "Report on OMAR and SIDEWINDER for period 1 December to 19 December 1951," BuOrd Project Officer for Sidewinder and OMAR to Branch Head Re9 (BuOrd), via Re9a.
5. Memo Re9a-HES:vd Ser 32589, 15 Jan 1952, Chief, BuOrd, to Commander, NOTS.
6. Rear Admiral Thomas J. Christman interview with Dr. Ron Westrum, 11–12; S-196, 29.
7. Christman interview with Westrum, 12.
8. Amlie, S-199, 31.
9. Experimental officer's trip report, NP45-14, 6 Dec 1951, 3.
10. Memo BOPOSO Serial #5, Encl. 1, "Report on Presentation to Mr. Keller (G/M Coor), 11 December 1951"; personal ltr, 21 Dec 1951, Moorer to Thompson.
11. S-112, 34.
12. Memo Re9a-HES:gs S78-1(126) Ser 32472, 14 Jan 1952, "Projects OMAR and SIDEWINDER; information on Bureau of Ordnance plans concerning," Chief, BuOrd, to Commander, NOTS (CwPPR).
13. Office memo, 24 Jan 1952, "Limitation on Contracts, SIDEWINDER and OMAR," Head, AOD, to Technical Director.
14. S-112, 80.
15. Wilcox ms, SW-2, 8.
16. Naval Dispatch 041808Z, 4 Apr 1952, NOTS Inyokern to BuOrd Section Re (CwPPR).
17. Research Board minutes, 7 Apr 1952, 5–6.
18. Memo Re9a-HES:mel S 78-1(126), 28 Jul 1952, "Projects SIDEWINDER and OMAR; responsibilities for," Chief, BuOrd, to Commander, NOTS (CwPPR).
19. Amlie, who arrived in China Lake that July just in time to experience the magnitude 7.7 earthquake centered in nearby Tehachapi, had just finished his Ph.D. requirements at the University of Wisconsin. He had been in the Navy during World War II, and toward the end of the Korean conflict, the Navy recalled him to active duty, with orders to report first to sonar school in San Diego, then to a minesweeper. But Moorer intervened to bring Amlie to NOTS, where he was assigned to perform REAC simulations for both Sidewinder and OMAR. After Amlie's release from active duty in 1954, he joined the civilian work force. The only station employee ever to jump from division head to China Lake's top civilian job, Amlie was head of Development Division 4 in AOD when he was named technical director in March 1968. He left that post in March 1970, subsequently becoming a weapons analyst for the Federal Aviation Administration and the Air Force.
20. Amlie review comments, 7 Mar 1998.
21. Wilcox ms, SW-1, 17–18; LaBerge, S-178, 3.
22. S-196, 5.
23. Memo Re9a-MHS:hl S78-1(126) Ser 006866, 31 Oct 1952, "Project OMAR; revised status report and planning of," Chief, BuOrd, to CNO (Op-51); Rugg ms, 122; Wilcox, S-196, 6.
24. S-200, 18.

25. Loranger was later the primary test pilot for BOAR. In 1965–66 he returned to China Lake as a captain and commanding officer of VX-5. In a subsequent Naval Air Systems Command assignment, he was the program manager for all antiradiation missiles (Shrike, HARM, and Standard ARM).

26. NAVORD Report 3373, NOTS 952, *Preliminary Tests for Project Spot,* by D. G. Wilson, H. L. Anderson, J. Nicholson, AOD, NOTS, 14 Oct 1954, 2–7, 31 (CwPPR).

27. Walker, who became the station's experimental officer in June 1954, was one of a series of officers in that position who went on to attain the Navy's highest positions. A 1939 graduate of the Naval Academy, he had also taken a tour at Los Alamos during World War II. He commanded fighter squadrons on the carriers *Coral Sea* (CVB-43) and *Valley Forge* (CV-45), then served three years at Sandia Base before going to Moffett Field. His Navy career culminated in three stars and the post of Commander Naval Air Force Pacific Fleet.

28. NAVORD Report 3373, NOTS 952, 16–17; Research Board minutes, 4 Nov 1953, 2–4.

29. These stout reinforced concrete walls were constructed during World War II as targets for Tiny Tim tests; the designation "Sandquist pyramids" honored the station's master builder, Captain Oscar A. Sandquist, who was the NOTS officer in charge of construction in 1944.

30. NAVORD Report 3373, NOTS 952, 32–33.

31. Research Board minutes, 10 May 1955, 1–2.

32. Wilcox ms, SW-1, 18

33. Amlie, S-199, 31.

34. Paper, "Proposed Reorganization of Aviation Ordnance Department," prepared 28 Oct 1952 and presented to the Research Board by McLean; Research Board minutes, 29 Oct 1952, 3.

35. Memo NP45-35 Ser 105, 4 Jun 1952, "Responsibilities on SIDEWINDER-OMAR Program as of 1 June 1952," Head, AOD, to distribution.

36. T. A. Marschak, "The Role of Project Histories in the Study of R and D," Rand Corp., Santa Monica, Jan 1964, 111.

37. "Views of Wally Schirra," *News and Views,* Mar–Apr 1969, 1; Schirra, S-137, 1.

38. Ltr, 22 Aug 1952 Howie W. [Wilcox] to Dr. Wm. B. McLean, c/o Robert N. McLean, Jr., Wapato Lake, Washington. The test is also described in TM 1653, 27.

39. Memo 35/WBM/meh Ser 150, 18 Sep 1952, "Semi-Monthly Summary of Progress, Period 1–15 September 1952," Head, Aviation Ordnance Dept., to Technical Director.

40. Memo 35/WBM/meh Ser 148, 5 Sep 1952, "Semi-Monthly Summary of Progress, Period 15 to 31 August 1952," Head, Aviation Ordnance Dept., to Technical Director.

41. TM 1653, 28–30.

42. Memo Op-512B/jek Ser 0022P51, 11 Mar 1952, "Navy Guided Missile Program," CNO to distribution (RG38).

43. S-112, 35; similar reminiscence in Wilcox interview, NL-T25, Sep 1980, 10–11 (NL).

44. Ltr, 22 Dec 1952, Sawyer to Thompson (TPR).

45. Neufeld, 93–96.

46. Other members were Fred Darwin from OSD; Navy representatives Rear Admiral J. H. Sides, Captain W. F. Raborn, and Lieutenant Commander. R. T. Tolleson; Army representatives Brigadier General K. F. Hertford, Brigadier General H. McK. Roper, and Lieutenant Colonel J. D'Arezzo; and Air Force representatives Major General D. N. Yates, Colonel R. L. Johnston, and Lieutenant Colonel P. J. Schenk. USAF memo for record, 10 Aug 1953, "8th Meeting of the Ad Hoc Committee on Guided Missiles," by Peter J. Schenk, Lieutenant Colonel, USAF (RG38).

47. Office memo, 11 Aug 1953, "SIDEWINDER Committee, Visit of," Aide to Commander (CwPPR).

48. Wilcox, S-196, 30; Christman interview with Westrum, 42; paper 3525/KJH:yh Ser 0404, 10 Feb 1954, "Summary of Sixth Sidewinder Planning Conference 10–11 February 1954," 1. The report, TM 1653, is perhaps the most complete and authoritative source of information on the early Sidewinder tests and is a prime source of information for this book. Christman also took on the task of saving the project's most significant correspondence, a contribution for which historians can be thankful.

49. Neufeld, 96–97; York and Greb, 21. An important offshoot of the committee's work was the 1953 establishment of the influential Strategic Missiles Evaluation Committee. Joining manager John von Neumann were George Kistiakowsky, Simon Ramo, Herbert York, Jerome Wiesner, and others. Committee recommendations had important consequences, particularly in the establishment of several high-priority rocket-powered ballistic missile programs.

50. TM 1653, 30; Wilcox ms, SW-1, 14–15. "I think it was a very gutsy decision, a very courageous decision, and it was borne out by the events, namely that we did eventually solve the wobble problem," Wilcox said in S-196, 43.

51. Test Report 30-213, NOTS No. 700, "Flight Test of Sidewinder Missile RAAM-N-7a1 Serial No. 1," by D. Grasing, Project Engineering Office, Test Dept., 16 Dec 1953, 1–4.

52. Cartwright and his wife Miriam S. "Mim" Cartwright both earned Ph.D.s in physics from UC Berkeley, and both were recruited for NOTS by Howie Wilcox, who had been one of Frank Cartwright's instructors at Berkeley. Cartwright became head of the Sidewinder program, then of the Air-to-Air Weapons Division. Mim Cartwright had a distinguished career in the Weapons Planning Group. The Cartwrights left NOTS in 1961. After 10 years in industry, working for General Motors, Philco-Ford, and Sparton Corporation, they returned in 1971 to China Lake, where he led the Missile Systems Development Division, then was special advisor to the technical director. Both Cartwrights retired in 1986.

53. Cartwright, S-194, 49.

54. TM 1653, 49.

55. Memo BOPOSO Serial #047, 7 Mar 1952, "Report on SIDEWINDER for period 31 January 1952 to 29 February 1952," BuOrd Project Officer for Sidewinder and OMAR to BuOrd Branch Head Re9 via Re9a, Appendix 1, I-1 to I-2.

56. Wilcox, S-112, 71–72; S-196, 38–39; NL-T25, 8–9 (NL).

57. Memo 352/HAW:md Ser 14, 11 Feb 1953, "A-Type Gyro Wobble Phenomenon," Code 352 to all section heads, Code 352, 1–2 (CwPPR).

58. Amlie, S-199, 67–68; Amlie review comments, 7 Mar 1998.

59. The patent is briefly described, along with others significant to Sidewinder, in NOTS 2068, 47. Another Stewart invention of significance to the Sidewinder story was the "inside-out, top-hat gimbaled joint," a crucial improvement to the 1A version of the missile. The inventive Stewart met a tragic end in the late 1960s, when he perished during a mudslide in the vicinity of California's Mt. Baldy, where he and his family had a cabin.

60. Jagiello, S-168, 12.

61. Cartwright, S-194, 3; Wilcox ms, SW-2, 16.

62. Amlie, S-199, 34.

63. Wilcox ms, SW-2, 16.

64. The test documentation does not reveal the identity of the pilot for this historic event.

65. Cartwright, S-194, 16–17.

66. S-112, 57–58; Amlie review comments.

67. Research Board minutes, 14 Sep 1953, 1.

68. After Wilcox drew the series on a large sheet of white butcher paper, the cartoons were prominently displayed at one of the Aviation Ordnance Department's many parties. "I whipped

up a bunch of these stick-figure cartoons, and we mounted this thing on the wall, and a lot of people admired it, but to me it was a work of 10 minutes to do it," Wilcox said in S-196, 79.

69. Stroop, S-191, 3, 58; see also LaV McLean, S-210, 9.

70. Ltr, 16 Sep 1953, "Note to Drs. Brown and McLean," Rear Admiral W. S. Parsons, BuOrd, to Dr. Fred K. [*sic*] Brown, Technical Director, NOTS (CwPPR).

71. Ltr, 18 Sep 1953, Thompson, Office of the Assistant Secretary of Defense, to Dr. W. B. McLean, NOTS (TPR).

72. Wilcox ms, SW-2, 18.

73. TM 1653, 37.

74. "X-9 Propellant and Sidewinder Gas Generator," based on technical notes by Douglas D. Ordahl, *Rocket Quarterly*, Mar 1954, 7–11. Gey, who had worked as a chemist for DuPont through the war years, arrived at NOTS in 1946. In the mid-1950s he began preliminary investigations of metal-fluorocarbon-explosive mixtures that led in the 1960s to China Lake's pioneering work in fuel-air explosives.

75. Benton, S-193, 52–53; Research Board minutes, 13 Sep 1955, 3.

76. Wilcox ms, SW-2, 18.

77. Research Board minutes, 2 Nov 1953, 5.

78. Some disagreement exists about which pilot fired at which test. Anne Nancy Carter, who was keeping documentation on the flights, stated that Al Yesensky, officer-in-charge of Guided Missile Unit 61, was the pilot on "the day Mickie Benton's son was born," 9 Jan 1954 (Carter, S-198E, 23). In S-193, 11–12, Benton remembered seeing the damage to the drone, then taking his wife to the hospital for his son's birth.

79. Wilcox ms, SW-2, 17.

80. Paper 3525/KJH:yh Ser 0404, 10 Feb 1954, "Summary of Sixth Sidewinder Planning Conference 10–11 February 1954" (RG38).

81. S-188, 19.

82. Benton, S-193, 42.

Chapter 12

1. Jack Crawford recalled that the flash would light up his bedroom like daylight even though the room faced the opposite way and that 12 minutes later the shock wave would arrive with a boom. After a friend picked up a signal from the test control site on his short-wave radio, the two were able to decode enough information to determine when the next test was scheduled. "On many test nights I left at 2 a.m. with some friends and a portable short-wave receiver and drove to Aguerreberry Point overlooking Death Valley," Crawford remembered. "From this vantage point, 80 miles and almost line of sight to the test site, we could set up cameras and get good home movies and still pictures of the shot and resultant mushroom cloud." S-171, 78.

2. According to Ashworth, Project Camel was so named "because the camel had gotten his nose under the tent, Parsons being the camel." S-226, 31.

3. Groves remembered years later that he approved of the runway extensions because of the argument that otherwise the runway would be too short for the B-29s the station was using to conduct tests of the A-bomb shapes. S-42, 22–23. Groves Street School, named for General Groves, saw its last pupils in 1995, after the Navy got out of the civilian housing business at China Lake.

4. Smith, S-177, 17.

5. RM 1, *Salt Wells Pilot Plant Story 1945–1954*, by K. H. Robinson, 11.

6. Research Board minutes, 24 Aug 1949, 2.
7. S-177, 8.
8. *Rocketeer*, 2 May 1951, 1; 12 Sep 1951, 1.
9. Paper 6001/KHR:bj Reg 60-11680, 19 Feb 1954, "General History of the Salt Wells Pilot Plant," submitted to Starnes Co. as Encl. 1 to memo, P5560/VG:mp A10-1 Ser 14, 3 Mar 1954, "Salt Wells Pilot Plant, information on," Vance Gudmundsen, Code P5560, to Starnes Co., 2; informal paper, "Summary of Unclassified Information on NOTS Atomic Work," by Code 75201, Jan 1967, 12.
10. Paper 6001/KHR:bj Reg 60-11680. The original mission of Salt Wells was to develop, refine, improve, and produce high-explosive components for atom bombs.
11. Research Board minutes, 12 Apr 1955, 2–3. Sage kept his hand in at NOTS for six more years as an independent contractor in the propellant field.
12. RM-1, 12-13, 32.
13. *Rocketeer*, 16 Jan 1952, 6. Robinson, who was instrumental in founding both the concert association and the Maturango Museum, was also the first head of NOTS' Technical Information Department, formed in June 1954. He died 19 November 1979. The band in which he was the bass player is still performing in Ridgecrest as the Ken Robinson Dixieland Band.
14. Levering Smith, S-177, 12–13.
15. *Rocketeer*, 22 Oct 1954, 6; 31 May 1957, 1. Barney Smith was a classic NOTS maverick with an unusual technical background. He had begun work on the desert in 1948 immediately after his graduation from Reed College in Portland, Oregon, at the relatively ancient age of 38. His interest in rockets, however, began so early that, in a station full of rocket experts, he was the one with the most years of experience. In 1932 at Staten Island, he had conducted the first public demonstration of a liquid-fueled rocket in America. (*The Chronology of Missile and Astronautic Events*, compiled by the Committee on Science and Astronautics, 87th Congress [8 Mar 1961], notes that the first American Rocket Society liquid-fueled rocket test was conducted at Staten Island on 14 May 1933.) Smith's leadership of several successful rocket projects at NOTS led to his rise to head the Weapons Development Department in 1958. He left NOTS in 1960 to become chief engineer for the Bureau of Naval Weapons. He subsequently spent a year at the Naval War College and a year in Europe studying R&D activities of NATO countries, then served from 1964–73 as technical director of the Naval Weapons Laboratory (later the Naval Surface Warfare Center), Dahlgren, Virginia.
16. *Looking Ahead From Way Back*, 44–45. In an 11 August 1999 ltr to the author, Smith commented that technician Louis Alpert was a "key honcho" on both the Big Stoop and the BOAR efforts, "making drawings, checking construction, and reducing test results. NOTS had many like him."
17. In comments Phil Arnold made in a 1994 meeting on China Lake guided-missile resources, he remembered having seen a film of the Big Stoop tests that documented this exodus.
18. Baar and Howard, *Polaris!*, 15.
19. Research Board minutes, 21 Jan 1952, 6; Smith, S-201, 12.
20. RM-3, 91.
21. S-181, 24–25. During his 34-year career at China Lake, Lotee served as head of the Rocket Development Department's Ordnance Components Division, then the Engineering Department's In Service Weapons Support Division (later called the Fleet Engineering Division).
22. This description of the station's work and several other improvements to the Elsie section came from Frank Knemeyer's February 2005 review comments.
23. Knemeyer review comments.

24. Research Board minutes, 9 Oct 1951, 4.

25. *Rocketeer*, 12 Jul 1957, 1; Hansen, 142. Starting in late 1957, the Mk 91 bomb was retired from the nation's nuclear weapons stockpile; the last unit was withdrawn in 1960.

26. Knemeyer, S-200, 10–14.

27. Hansen, 180.

28. Research Board minutes, 27 Nov 1951, 3.

29. S-177, 10–11.

30. Research Board minutes, 3 Dec 1951, 3.

31. Hansen, 180; memo, NP45-01, 27 Mar 1952, "Memorandum for Advisory Board Members," F. W. Brown.

32. Hansen, 180.

33. Riggs, S-136, 47; Porter, S-216, 51.

34. Porter, S-216, 45–56. Porter had just graduated from the University of Washington when he began work on BOAR in January 1953 as a junior professional employee of the Ballistics Division. His successful career on the desert culminated in his appointment as China Lake's last technical director in October 1989. He retired from that position in January 1993, having worked for the Navy's desert lab for 40 years to the day. After retirement he volunteered countless hours to efforts supportive of military facilities in the southwestern U.S.

35. Amlie, S-199, 25; Riggs review comments.

36. McLean, "Progress Report on the Technical Program," 6.

37. *Rocketeer*, 5 Feb 1954, 1; 26 Feb 1954, 1, 5; 5 Mar 1954, 1.

38. Plans for a third facility, the PanTex Ordnance Works, Amarillo, Texas, fell through. As with Burlington, the Salt Wells staff had been asked to furnish advice and operational and equipment assistance to the contractor, a division of the Proctor and Gamble Company. China Lakers provided this assistance as before, with frequent meetings and sharing of key equipment designs. The PanTex plant had been planned for production in 1953, but developments in the field of nuclear energy had forced reassessment of production needs. RM 1, 13–15.

39. It was at the urging of Parsons and Lauritsen that a pilot plant for manufacture of high-explosive lenses was built at Salt Wells during World War II. Parsons saw NOTS' work as so important that within two days after the first atom-bomb explosion at the Trinity site, he briefed the station's top leaders at China Lake. His next stop was Tinian, where he was in charge of final preparations for the atom bomb drop over Hiroshima (a flight on which he controlled many of the critical decisions as weaponeer, the person who supervised arming of the bomb and directed its delivery). *Rocketeer*, 1 Nov 1968, 4.

40. RM-1, 16–17, 33–34.

41. *Rocketeer*, 26 Mar 1954, 8; 9 Apr 1954, 1; 21 May 1954, 1; 17 Sep 1954, 2. An unknown number relocated to other installations within DoD; Lou D. Pracchia commented in his review that several former NOTS employees came to Seal Beach, where he worked at the time.

42. "Annex Management Issues Policy Statement," *Rocketeer*, 12 Mar 1954, 3; 1 Jul 1955, 3; special issue, "12 Years of Progress," 8 Nov 1955, 5.

43. Memo Fila-1-JCM:ey NP36, 19 Oct 1954, "Report of Internal Audit No. A91—U.S. Naval Ordnance Test Station, Inyokern, California; forwarding of," Encl. 1, Copy of subject report, Chief, BuOrd, to Commander, NOTS; *Rocketeer*, 8 Mar 1957, 4; Source Cards for NOTS Presentations, Presentations Div., Technical Information Dept., Apr 1956.

44. A member of what China Lakers called the "Idaho Mafia," Skaar was one of many University of Idaho graduates hired by NOTS. He arrived in 1946, after working as an experimental chemist for Spreckels Sugar Company. He spent the last 14 of his 30 years at China Lake as the first head of the Safety Department. The Kit Skaar Award, established at China Lake in 1983, recognizes outstanding firing-officer performance.

45. *Rocketeer*, 8 Mar 1957, 4.

46. Plastic-bonded-explosive warheads for both Sidewinder and Shrike were among the early applications of the technology. So stable were the NOTS PBX systems that the explosives could be cast-loaded directly into warheads.

47. Research Board minutes, 13 Aug 1954, 2; 15 Nov 1954, 2.

48. Research Board minutes, 16 Dec 1954, 1–22; 8 Feb 1955, 2; 22 Mar 1955, 3; 12 Apr 1955, 3; 6 Apr 1955, 1; 10 May 1955, 2.

49. NAWCWPNS AdPub 019, *History of the Naval Weapons Evaluation, Facility, Albuquerque, New Mexico 1948–1993*, Technical Information Dept., China Lake, Mar 1993.

50. Ray Miller ltr to the author, 29 Sep 1999; *CPIA Bulletin*, Johns Hopkins University Applied Physics Laboratory, Chemical Propulsion Information Agency, Vol. 8 No. 2, Feb 1982, 6–7.

51. Sapolsky, *Polaris System Development*, 3–4.

52. Perry, "The Interaction of Technology and Doctrine in the USAF," 393–394.

53. BA-11, 18 (NL).

54. The events leading up to the establishment of SPO and the Jupiter-S program are described in Davis, *The Politics of Innovation, Patterns in Navy Cases,* 32–40; Sapolsky, 16–22, 27; Paolucci, "The Development of Navy Strategic Offensive and Defensive Systems," 214–215; and in Knemeyer, "Concept Formulation of the Navy's FBM," *The China Laker* (newsletter of the China Lake Museum Foundation), Fall 2003, 1, 10–12.

55. Isenberg, 663.

56. Smith, S-201, 20.

57. Others Bothwell assigned to the team in addition to Witcher and Knemeyer were D. S. Bloom, Prescott Crout, C. M. Arney, Glover S. Colladay, Peter Kim, M. D. Insley, and R. Lucas. Bothwell had an impressive teaching and research background at MIT, the University of Chicago, and Northwestern University. He arrived at NOTS in 1950 as liaison scientist for Project Chore, an ordnance study contracted to the University of Chicago. Surprised and pleased by the intellectual atmosphere of the station, Bothwell decided to stay, entering the NOTS rolls in 1951 as consultant to the technical director and becoming head of the Central Evaluation Group in 1954. Bothwell left China Lake in 1959, continuing to serve as a consultant for several years thereafter. He received the L.T.E. Thompson Award in 1961; see Appendix B for the citation. 58. Knemeyer, S-200, 26. Much of the information in this section is also from Knemeyer's "Concept Formulation of the Navy's FBM."

59. Smith, S-177, 45–46.

60. Knemeyer, "Concept Formulation," 11; S-177, 36–37.

61. S-177, 37–38.

62. Armacost, *Politics of Weapons Innovation*, 108–110.

63. A direct outgrowth of the Mercury and Atlantis efforts was Project Michelson, an ambitious study that began at China Lake in 1960 and that developed theoretical bases for the determination of the forms of influence that would most effectively discourage attacks on the United States under a wide variety of circumstances.

64. Comment to the author, June 1994. Arnold arrived at China Lake fresh from Oklahoma A&M (now Oklahoma State University) in 1955 when the emphasis on nuclear weapons was at its height; his first work was on the warhead for Diamondback. He subsequently worked on Sidewinder, Shrike, Agile, Bulldog, and many other projects; became head of the Weapons Planning Group, "the best job in the Navy," in 1982; and retired from China Lake in 1994. After retirement he worked tirelessly for more than a decade on efforts supportive of military facilities in the southwestern United States.

Chapter 13

1. Schoeffel Naval Institute oral history, 300 (OA).
2. The report (NavOrd 1760) is classified, but its findings are summarized in RM-3, 200–202.
3. Renzetti earned bachelor's, master's, and doctor's degrees at Columbia University, where he was a research associate in atomic physics under the famed physicist, Dr. I. I. Rabi. During World War II Renzetti was a BuOrd specialist in mine protective equipment for ships and technical director and administrator of countermine warfare for the Twelfth Naval District. He joined NOTS in November 1944 and became successively head of the External Ballistics Section, of the Measurements Division, of the Test Department, and in August 1950 of UOD. He left the station in 1954 for a position with the Southern California Air Pollution Foundation in Los Angeles.
4. Paper, "Summary of the Underwater Ordnance Department Program for the NOTS Advisory Board," 25 Oct 1951, 4 (TPR); Research Board minutes, 20 Dec 1951, 3.
5. Research Board minutes, 13 Nov 1951, 5.
6. Undated draft memo (circa Feb 1952), "U.S. Naval Ordnance Test Station, Inyokern, California; Responsibilities in the Torpedo Program; assignment of," Chief, BuOrd, to Commander, NOTS.
7. Memo P0112/RCD:pec, 22 Aug 1952, "Comments on the Torpedo Program," R. C. Davis to Technical Director; Research Board minutes, 22 Oct 1951, 6–9.
8. NOTS 568, *Design and Production Department Operations Fiscal Year 1952*, 30 Sep 1952, 27.
9. Kunz, S-104, 5.
10. W. W. Safford, "Technical Direction of Torpedo MK 43 Mod 0," NOTS 673, *Quarterly Bulletin, Activities in the Torpedo Program*, 1 May 1953, 27–28.
11. Research Board minutes, 6 Sep 1949, 2; NWCV2, 80–81.
12. Talkington, "NOTS, San Clemente Island," 92–93; *San Clemente Island Master Plan*, Western Div., Naval Facilities Engineering Command, Mar 1977, B8–B13.
13. Research Board minutes, 3 Oct 1949, 14–16; 3 Jan 1950, 1,
14. Gleb Spassky, "Island Range for High Velocity Rockets," Part 1 in *Rocketeer*, 31 Jan 1951, 6; Part 2 in *Rocketeer*, 7 Feb 1951, 3. See also "New Laboratory and Office Building, Pasadena Annex," an unattributed 1950 study, 13–14 (NOSC papers).
15. Report #11-527, "Potential for Reducing Personnel and Facilities at San Clemente Island," Central Staff, Naval Undersea Research & Development Center, San Diego, Jan 1970, 5.
16. Spassky, Part 2, 3.
17. Report #11-527, 5.
18. Jennison, S-99, 22–24.
19. Campbell, S-174, 5–6; launching ceremony described in *Rocketeer*, 31 Oct 1951, 3.
20. A. C. Bravo, "Development of the Long Beach Test Ranges," NAVORD Report 2041 NOTS 720, *Quarterly Bulletin. Activities in the Torpedo Program,* Underwater Ordnance Dept., NOTS, 1 Aug 1953, 3–4.
21. Halley Wolfe, "Studies of Acoustics of the Medium," NAVORD Report 3497 NOTS 1121, *Torpedo Quarterly. Bulletin of Activities in the Torpedo Program*, UOD, NOTS, May 1955, 13–17. Wolfe was another Caltech man, having earned all of his degrees there. After acquiring his Ph.D. in 1935, Wolfe contributed to the motion picture industry in cartoon equipment and sound technology. He started work at the Pasadena Annex in 1950 as an acoustics consultant in UOD.

22. OPNAV Report 5750-5, 92; *Rocketeer*, 8 Nov 1958, 7.
23. *Rocketeer*, 18 Sep 1953, 3; and 8 Nov 1955, 5.
24. John Cox review comments, Jun 1998.
25. *Rocketeer*, 1 Aug 1951, 1.
26. Jennison, S-99, 17–18; memo, NP45-11 Ser 4115, 26 Oct 1951, "New Designation for McCornack Hospital Activities," Commander, NOTS, to Chief, BuOrd.
27. Report Op-83/LMR Ser 162PO8, 21 Apr 1952, "Naval Ordnance Test Station Inyokern, China Lake, California; Industrial Survey Division Report No. 157," Naval Inspector General to Chief, BuOrd; Chief, BuAer; CNO; et al.; Encl. 1, rough draft of report, 24–25 (TPR).
28. NOTS 543, *Torpedo Mk 32 Mod 1 Progress Report, 1 January to 31 March 1952,* NOTS, Inyokern, Jul 1952.
29. *Rocketeer*, 25 Feb 53, 3.
30. RM-3, 202–204.
31. *Rocketeer*, 14 Mar 1958, 1.
32. Smith, *Looking Ahead From Way Back*, 47–48. RM-3, 83, gives mid-1951 as the date of the task assignment.
33. Safford, NOTS 673, 27–30.
34. Leonard Freinkel, "Rocket-Assisted Torpedo," NAVORD Report 2097 NOTS 855, *Torpedo Quarterly*, May 1954, 8–10; *Rocketeer*, 14 Mar 1958, B-3.
35. Smith, *Looking Ahead from Way Back,* 50; Memo 01/WBM:nft, 27 Sep 1954, "Trip Report, 21–23 September 1954, Washington, DC," Technical Director to files.
36. C. C. Wheeler and Earl Howard, "Plastic Frangible Nose Caps," NAVORD Report 2086 NOTS 823, *Torpedo Quarterly*, Feb 1954, 5–7.
37. Harry Humason, "Producibility Features of the RAT Airframe," NAVORD Report 3372 NOTS 951, *Torpedo Quarterly*, Nov 1954, 7–14; *Rocketeer*, 14 Mar 1958, B-2.
38. Hooper Naval Institute oral history, 264–265 (OA). Another Aliex recommendation resulted in the submarine rocket (SUBROC) program, to which the Pasadena Annex would contribute expertise starting in 1958.
39. NOSC TD 1940, *Fifty Years of Research and Development on Point Loma, 1940–1990*, Naval Ocean Systems Center, San Diego, Sep 1990, 52.
40. Moore, S-185, 18–22.
41. According to Saholt, the man sent to represent China Lake at an important meeting fell asleep at a critical time, thus losing the ASROC work to Pasadena (Saholt comments to the author, 23 Mar 1999).
42. In *Looking Ahead From Way Back*, 50–51, Smith recalled, "The diadem in my tiara of fancy projects was taken from me forthwith, leaving my crew and me totally embittered." Although he stayed on until 1960, that disappointment appears to have been the beginning of the end of his tenure at China Lake.
43. Memo 15/HGW:dd, Reg 151488, 17 Feb 1956, "Long Range RAT and ASROC Weapon System," Technical Director to Distribution.
44. *Rocketeer*, 14 Feb 1958, 1.
45. Research Board minutes, 13 Aug 1957, 2; and 26 Nov 1957, 2.
46. Pasadena Annex Notice 2150, P19/JJO'B;mg, February 10, 1958, "RAT Press Release," Officer in Charge, Code P19, to All Hands; Administrative Board minutes, 9 Dec 1958, 3.
47. OPNAV Report 5750-5, Encl. 1, "Basic Information on U.S. Naval Ordnance Test Station China Lake, California. In Reply to Secretary McNamara's Task No. 97," 4.
48. S-197, 41.
49. W. S. Fraim, "Mark 48 Torpedo," *Naval Ordnance Bulletin*, Sep 1972, 4–7.
50. OPNAV Report 5750-5, 11.

Chapter 14

1. S-21, Nov 1966, 36–37; and S-15, 44–45.
2. Patton, S-179, 81.
3. Advisory Board minutes, 19–21 Nov 1953, 22–23. In addition to Parsons, prominent visitors at that meeting were Dan Kimball, president of Aerojet-General Corporation and former Secretary of the Navy (a position he had left only the previous January); Dr. C. C. Bramble, technical director of the Naval Proving Ground, Dahlgren; Dr. R. D. Huntoon, technical director, Naval Ordnance Laboratory, Corona; Dr. R. D. Bennett, technical director, Naval Ordnance Laboratory, White Oak; and Captain E. L. Woodyard, NOL commander.
4. Wilson, S-96, 35; Mrs. Robert Burroughs (formerly Mrs. William S. Parsons), S-10, 47–48.
5. Research Board minutes, 1 Mar 1954, 2–3.
6. Ltr, A-MFS:fk, 23 Mar 1954, Schoeffel to McLean (McLPR).
7. Advisory Board minutes, 11–13 Mar 1954, 21–23.
8. S-191, 13–15.
9. Ward, S-94, 14.
10. S-97, 25.
11. S-177, 56–57.
12. Ltr, A-MFS:fk, 23 Mar 1954, Schoeffel to McLean (McLPR).
13. Ltr, 2 Apr 1954, McLean to Schoeffel, copy to 00, P16, All Dept.. Heads, 11, 17, 14, 15, 12.
14. Booz, Allen R&D management study, 129–130.
15. McLean "may have been on a first-name basis, but that does not mean he remembered the names of all those outside the Sidewinder group. One of my first jobs in the Presentations Division was to put organization charts with the pictures of all persons at branch head level and above—for his benefit," Al Christman recalled in review comments.
16. S-94, 16.
17. Moore, S-185, 24. Moore arrived at NOTS in July 1954 after graduating from Texas A&M College. At first he wasn't sure he wanted to be an engineer, but he had so much fun that he stayed for 13 years. One of his favorite jobs in the Surface Weapons Division of the Rocket Development Department, a division of few people but much brainpower that Barney Smith referred to as "small like a pearl." In 1964–67 as head of the Astrometrics Division (renamed the Undersea Systems Division in 1967), Moore worked on a wide variety of projects, reaching an understanding with Knemeyer, his department head, that Moore's group would take on McLean's projects, leaving the rest of the department focused on more pragmatic endeavors.
18. *Rocketeer*, 7 May 1954, 2.
19. S-177.
20. Ward, S-94, 17.
21. Wilson, S-96, 20–21; Saint-Amand, S-120, 29–30; McLean, S-97, 20–21.
22. Memo NP45-0110/A-10, 11 Mar 1952, "Policy and Organization of Station Evaluation Program," Technical Director to distribution (departments)
23. *Rocketeer*, 20 Aug 1954, 1.
24. "I like Bill personally, but administratively I couldn't see through the fog," Ellis said later (S-77, 60). From late 1954 to 1957, Ellis was director of planning for Rheem's Government Products Division. From 1957 to 1961 he was a member of the Institute for Defense Analyses at the Pentagon where he participated in evaluations of the effectiveness of new systems, including intercontinental ballistic missiles. In retirement he lived for many years in Kernville, California, eventually moving to Santa Maria, where he died in 2003 at the age of 97.

25. Research Board minutes, 24 Aug 1954, 3; Memo 01/WBM:nft (0155), 6 Jan 1955, "Weapons Planning Group; establishment of" Technical Director to NOTS organizations.
26. Carl L. Schaniel, "Operations Analysis and the Naval Weapons Center," *News and Views*, Aug–Sep 1967, 3.
27. Research Board minutes, 10 Nov 1952, 2.
28. Research Board minutes, 28 Sep 1953, 5.
29. "The Unguided Missive," Edition 6, 20 Oct 1955, 1. Sandshell did not perform as expected, primarily because the expected customers failed to materialize.
30. Thelma St. George, "Flexibility Is Keyword in Performance of Weapons Development Assignments," *Rocketeer*, 8 Nov 1958, 3.
31. S-225, 57. Polly Nicol recalled that when the McLeans left China Lake in 1967, "LaV said, 'Bill, you cannot take those Sears magazines any further.' He finally talked her into one for every five years. So he took his Sears magazines on to San Diego with him."
32. So famous was LaV's nut bread that when the McLeans left China Lake for San Diego in 1967, the organizers of her going-away party passed out nut bread to everyone there. Eleanor Lotee, S-181, 19.
33. S-225, 63–64.
34. LaV McLean taped recollections, Historical Society, 20 Sep 1988, 28.
35. S-210, 21–22.
36. Polly Nichol, S-225, 59, 62.
37. Taped recollections, Historical Society, 6–8.
38. S-191, 7. See also Eleanor and Ted Lotee, S-181, 18–19.
39. LaBerge, S-207, 4–5.
40. Nathan, S-190, 129; Hazel Coleman Nilsen and Rose Gonzales, S-206, 55.
41. Ward, S-94, 13.
42. *Rocketeer*, 13 Aug 1954, 1; 20 Aug 1954, 1; 17 Sep 1954, 1; 1 Oct 1954, 1; and 12 Nov 1954, 1.
43. Memo Op-02/rlc Ser 12P02, 20 Jan 1955, "Panel to Examine the Missions and Tasks of the Naval Ordnance Test Station, Inyokern, California," Secretary of the Navy to Assistant Secretary of the Navy (Air). The panel was chaired by James H. Smith, Jr., assistant secretary of the Navy for air. In addition to Stroop, the membership included Rear Admiral T. M. Stokes, director, General Planning Group; Rear Admiral John H. Sides, director, Guided Missiles Division; and Dr. Norris E. Bradbury, director, Los Alamos Scientific Laboratory.
44. Unattributed NOTS paper, 9 Jun 1955, "Naval Ordnance Test Station Comments on the Conclusions and Recommendations from the report of The Panel to Examine Mission and Tasks of the Naval Ordnance Test Station," 3. The task assignment came from Thomas S. Gates, acting Secretary of the Navy.
45. Advisory Board minutes, 5–7 May 1955, 19-3.
46. Wilson, S-96, 36.
47. Plain, S-108, 14.
48. Ashworth, S-226, 1.
49. *Rocketeer*, 10 Jun 1955. 1.
50. S-179, 75.
51. *Rocketeer*, 12 Aug 1955, 1; "Biography/NWC Commanding Officers #8."
52. Ashworth, S-226, 29.
53. Groves, S-42, 10, 38.
54. Ashworth, S-226, 54–55.
55. Davis, *The Politics of Innovation: Patterns in Navy Cases*, 11–20.

56. "Views of the Ex-Insider. The Fragility of NWC," *News and Views,* Naval Weapons Center, Oct 1973, 9; Ashworth, *News and Views,* 9.

57. Ashworth, "Some Thoughts on Better Laboratory Management," 4–5.

58. In 1958 when Ashworth was a rear admiral selectee serving as director, Atomic Energy Division, Office of the Chief of Naval Operations, he visited China Lake to receive the L.T.E. Thompson Award. See Appendix B for the citation. When Ashworth was assistant chief for RDT&E in the Bureau of Naval Weapons in the early 1960s, NOTS again was under his cognizance. He was a vice admiral when he retired from the Navy in September 1968, after tours as commander of the Sixth Fleet and deputy commander in chief of the Atlantic Fleet.

59. *Rocketeer,* 2 Nov 1956, 1.

60. S-34, 37. Commander (later Captain) John I. Hardy arrived in China Lake in November 1954 as an assistant experimental officer. He was the station's experimental officer from July 1955 to August 1957. His background included service in some of the hottest campaigns of the Pacific Theater in World War II, plus education at the Naval Academy and at MIT, from which he earned an M.S. in aeronautical engineering. After his first tour at NOTS, he served in increasingly responsible positions, including command of attack carrier *Hornet* (CVA-12). In August 1964 he and his wife Delores gladly returned for a second tour at China Lake, this time as NOTS' "first couple." Hardy served as China Lake commander until February 1967, leaving the desert to become assistant to the president at Case University of Technology, then director of engineering for Honeywell's Ordnance Division.

61. Booz, Allen R&D management study, 40, 43, 130–132.

62. Booz, Allen R&D management study, 46, 106.

63. Ashworth, S-226, 1–2, 5, 75–76. Chenault, the station executive officer from 1955 to 1958, was a Naval Academy graduate with extensive sea duty and technical postgraduate work in his background. He and his wife Katie were popular community members, and China Lakers welcomed both back enthusiastically when Chenault returned in 1966 to head the Engineering Department. In 1971 he and Dr. Ivar Highberg switched jobs; Chenault headed the Systems Development Department until his 1973 retirement. He died in September 1996.

64. William B. McLean, presentation to Jason Div., IDA, fall meeting, 31 Oct 1964, Arlington, Virginia, 1; S-97, 30.

65. Research Board minutes, 16 Aug 1955, 2.

66. Memo 01/WBM:nft (2155) , 5 Oct 1955, "List of Accomplishments," Technical Director to technical department heads.

67. Research Board minutes, 24 Jan 1956, 1.

68. Pollock, S-240C, 94–95.

69. Video production, "Secret City. A History of the Navy at China Lake."

70. S-97, 30.

Chapter 15

1. OPNAV Report 5750-5, 1.

2. Development of HPAA began in 1950, and the rocket was tested to a certain extent, but experimental production was delayed because of the 1952 reassessment that led instead to the decision to develop Zuni.

3. Hugh D. Woodier, "5.0-Inch Folding-Fin Aircraft Rocket (Zuni)," *Rocket Quarterly,* Jun 1955, 1–3.

4. Little review comments.

5. "Controlled Rocket-Warhead Fragmentation," based on technical notes by Gilbert Fountain, *Rocket Quarterly,* Dec 1953, 1–8.

6. Bowen, S-175, 6–7
7. *Rocket Quarterly*, Jun 1955, 6–9.
8. RM-3, 70, 73-77.
9. Research Board minutes, 22 May 1956, 2; and 25 Jun 1956, 2.
10. Research Board minutes, 22 May 1956; McEwan review comments.
11. Research Board minutes, 25 Jun 1956, 2; 11 Sep 1956, 2; and 8 Jan 1957, 2; OPNAV Report 5750-5, 35.
12. Stone, "Navy Shows Sidewinder's Lethal Power," *Aviation Week*, 11 Mar 1957, 26–27.
13. Marvin Miles, "Navy's Sidewinder Missile Downs Fighter in First Demonstration," *Los Angeles Times*, 4 Mar 1957, 21.
14. *Rocketeer*, 18 May 1957, 1, 3.
15. OPNAV Report 5750-5, 34–35. Although 1960 saw carrier units in both the Atlantic and the Pacific equipped with Zuni, cancellation of the program came shortly thereafter.
16. Patton, S-179, 4 Sep 1989, 2, 47–48.
17. Navy NOTS 11ND, *Summary of Major Accomplishments*, 1–4.
18. Research Board minutes, 1 Feb 1954, 1.
19. S-179, 6–7.
20. McLean, "Progress Report on the Technical Program," 4.
21. S-179, 7. As described in Chapter 7, NOTS developed the Antitank Aircraft Rocket (Ram) in less than a month in 1950 in response to an urgent need in Korea.
22. S-179, 3–4.
23. McEwan review comments; *Rocket Quarterly*, Jun 1954, 3.
24. Research Board minutes, 8 Mar 1955, 1; 22 Mar 1955, 1.
25. OPNAV Report 5750-5, 30; Administrative Board minutes, 21 Oct 1957, 2.
26. In review comments, Patton said that some of the later improvements to the 2.75-inch FFAR were made by the Naval Powder Factory at Indian Head, Maryland, to which much of the air-to-ground work was transferred.
27. Arthur C. Ellings, "Sidewinder From the Production Viewpoint," NOTS 2068, 43–44.
28. S-179, 42.
29. RM-6, 3–4.
30. Pearson arrived on the desert in 1951, after serving in World War II and earning an M.S. in applied mechanics from Northwestern University. During his long, distinguished career at China Lake, he earned an international reputation for his work in the interaction of explosives and metals for industrial and military applications. Known as "the father of explosive forming and welding," he made numerous contributions to explosives and materials research and authored or coauthored more than 100 technical publications and three books. His *The Behavior of Metals Under Impulsive Loads* and *Explosive Working of Metals*, both coauthored with Dr. John Rinehart, another China Lake pioneer in explosives research, have become classics in the field. Pearson was the head of the Detonation Physics Division of the Research Department when he retired in 1980.
31. RM-6, 3–20; RM-3, 114–115.
32. RM-6, 25.
33. Testimony of General Earle E. Partridge, Commander in Chief, Air Defense Command and Continental Air Defense Command, *Study of Airpower*, Hearings before the Subcommittee on the Air Force of the Committee on Armed Services, U.S. Senate, 84th Congress, 2nd Session, 30 Apr–1 May 1956, 249. According to Pat Patton, the F-86D Sabrejet was equipped with 24 FFARs, and the Northrop P-61 Black Widow had two wingtip pods each carrying 52 rockets, with this armament intended for air combat.

34. Doig review comments; NOTS 872, *Rocket Department Technical Appraisal,* 13; Wiegand review comments. In S-203, 10, Ellis noted that in about 1970 he was given a pin commemorating the manufacture of the 10 millionth Mighty Mouse. The rocket proved its effectiveness in 1957–58 during the conflict between Formosa (Taiwan) and mainland China, then was used by the millions in Vietnam. Later sharp-eyed China Lakers spotted the rockets and their pods as they watched television coverage of Desert Storm. Under the Army designation Hydra 70, the rocket is still a mainstay of the Apache attack helicopter arsenal.

35. Memo Re9c-GRB:mt X11 Ser 98433, 14 Apr 1955, "SIDEWINDER Missile; BuOrd Evaluation Program for," Chief, BuOrd, to Commander, NOTS (CPPR); Research Board minutes, 26 Jul 1955, 2; *Rocketeer,* 19 Oct 1956, 3.

36. Memo 9561/GAT:jwh A4-3 Ser 014-55, 8 Jul 1955, "First Supersonic firing of SIDEWINDER (dummy) missile and 5" high velocity aircraft rocket (HVAR); report of," Officer in Charge, U.S. Naval Guided Missile Unit SIXTY ONE, to Head, Missile Development Div., AOD (CPPR); Tierney, S-224, 37.

37. Amlie, S-199, 54.

38. NOTS 1739, *Sidewinder 1A,* Apr 1957, 3–7.

39. Cartwright, S-194, 21–22. Emphasis in the original.

40. Amlie, S-199, 54–55.

41. Freezing a version of the missile for production did not mean that work stopped on improvements, but simply that the particular version being produced would no longer see major changes. The team could then turn its attention to a new version that might incorporate more radical changes than could be accommodated economically on the assembly line.

42. Memo 35/WBM:bjs X11 Ser 0538, 9 Apr 1954, Commander, NOTS, to Chief, BuOrd.

43. Research Board minutes, 15 Sep 1954, 4.

44. Memo Re9c-JRB:mt Ser 92569, 11 Jan 1955, "An Air-to-Air Missile FOLDWINDER (Folding Wing SIDEWINDER) for Launching from Supersonic Fighter Aircraft; Development Plans for," Chief, BuOrd, to Commander, NOTS (CwPPR).

45. Ward informal memo, 5 Apr 1956, "NOTS Proposal Sidewinder 1A."

46. Rugg ms, vi; Research Board minutes, 26 Nov 1957, 1; S-168, 73.

47. Wilcox ms SW-2, 20.

48. Wilcox ms SW-2, 20–21. Peter Nicol said he appreciated the way Madden ran the branch. "He had no qualms at all about turning over your responsibilities to you and letting you get on with it. He'd give you the job, and, boy, from there on, it was yours and you'd better do it." Nicol, S-198D, 14–15.

49. Swann, S-198B, 28.

50. S-225, 28–29. Nicol also recounted this episode in S-198D, 5–6.

51. Cartwright and Swann, "How Sidewinder Solves Its Own Problem," NOTS 2068, 12.

52. NOTS 843, *AAM-N-7 Sidewinder U.S. Navy Air-to-Air Guided Missile,* 12 Apr 1954, 18.

53. Wilcox ms SW-3, 7–8.

54. S-112, 66–67.

55. NOTS 2068. 8. Wilcox claimed in "Research Problems Associated With the Development of Sidewinder" (presented at an ONR symposium, 19–20 Mar 1957, 4), that the 1952 Air Force offer was for $50 million, $20 million more than the Sidewinder program's total costs prior to fleet release in 1956.

56. S-178, 17–18. LaBerge remembered that this officer was Brigadier General Albert G. Boyd, commander of Edwards Air Force Base. LaBerge is the only source of this identity for the Air Force officer who came to China Lake to test-fire Sidewinder. Major Don R. Scheller, who was then the USAF development field representative at China Lake, remembered this important visitor as a General Wade from Wright-Patterson Air Force Base. See Westrum,

Sidewinder: Creative Missile Development at China Lake, 134–135. A search of Air Force online resources found no general with the surname Wade who had been stationed at Wright-Patterson.

57. Wilcox, S-196, 47–48. Wilcox expressed similar recollections in S-112, 13; Wilcox ms SW-3, 8–9; and NL-T25, 11–13 (NL).

58. Ellis, "Lauritsen's Legacy to the Naval Weapons Center," speech delivered at the dedication of Lauritsen Laboratory, China Lake, 18 Jun 1976 (EPR).

59. The committee's report to Secretary of the Air Force Harold Talbott in February 1954 urged a speed-up of the Air Force ICBM program. As a result of these findings, Talbott ordered an almost immediate acceleration of the Atlas program. See Neufeld, 93–105.

60. S-198, 48–49; S-112, 13–14; and NL-T25, 12–13 (NL). In these interviews Wilcox also remembered that Gardner agreed to sponsor a study, the results of which would be used to justify the Holloman tests. Since the date of the breakfast meeting is undocumented, the possibility exists that the meeting occurred prior to the Gardner Committee findings of August 1953, which authorized Sidewinder to proceed as planned. However, since the big push to sell the Air Force on Sidewinder did not occur until after the missile's first successful test shots, Gardner's intercession as recalled by Wilcox seems more likely to have been in closer juxtaposition with the Holloman shots.

61. Tierney, S-224, 25.

62. Memo 3012/wa:vew A1-1/SP-1 Ser 187, 22 Jun 1955, "SIDEWINDER Holloman Air Force Base Team; commendation letter of," Head, Branch B, Project Engineering Div., to Head, Test Dept.; Commanding Officer, NAF; Head, AOD; O-in-C, GMU 61 (Blaise papers from Westrum); McClung, S-188, 15.

63. Wilcox ms, SW-3, 10; Benton, S-193, 18–20.

64. S-193, 19.

65. S-112, 62–63; similar recollections may be found in NL-T25, 14–15 (NL).

66. S-224, 26.

67. Wilcox, NL-T25, 15–16 (NL). According to Rugg ms (123), the first target rocket used in the Sidewinder program was designed and built before March 1951 and used during the first sunseeker test. Target Rocket Model 5—a ramjet rocket specifically designed at NOTS for Sidewinder tests—was first used in late 1951 or early 1952.

68. Wilcox, NL-T25, 13 (NL); Wright Air Development Center Technical Note WADC TN 55-559, *Sidewinder Firing Tests With the F-86D and F-100A Aircraft,* by Veryl V. Vary, Wright Air Development Center Air Research and Development Command, USAF, Wright-Patterson Air Force Base, Ohio, Sep 1955, 4.

69. S-112, 65.

70. S-199, 32.

71. Research Board minutes, 13 Sep 1955, 3.

72. Cartwright, S-194, 11–12.

73. Memo 3011/RAB:wa A1-1/S-23 Ser 21, 17 May 1957, "IR Target Source for SIDEWINDER; history and recommendations for extended use of," Head, Sidewinder Branch, to Head, Project Engineering Div., NOTS; "Contributions of Balloon Operations to Research and Development at the Air Force Missile Development Center, Holloman Air Force Base, New Mexico 1947–1958," Historical Branch. Office of Information Services, Air Force Missile Development Center, Air R&D Command, U.S. Air Force, 1959, 41–51. McElmurry, who left an assignment to GMU-61 at NOTS to go to Holloman, had flown many of the Sidewinder test flights at China Lake and was considered "one of the boys" by the military-civilian team at NOTS. See Tierney, S-224, 59.

74. Anonymous NOTS informal paper, 9 Dec 1964, "Illustrations of NOTS' Role."

75. Amlie, S-109, 14; Boyle, S-180, 35; Research Board minutes, 26 Aug 1957, 1.
76. TP 2333, *Sidewinder 1C*, 22 Sep 1959, 6–9.
77. Younkin, "The Clan Sidewinder," 1 May 1979.
78. Amlie informal paper, "AIM-9C," late 1980, 1; S 199, 42. Amlie was promoted to head AOD's Development Division 4 (Weapons Systems) in 1958, when his predecessor, John Gregory, moved laterally within AOD to head Development Division 1 (Bomb Directors).
79. S-112, 29.
80. Ltr, 3 Jan 1956, "SIDEWINDER Material for OpDevFor evaluation," Commander, NOTS, to Distribution List C (CwPPR).
81. Research Board minutes, 8 Jan 1957, 2.
82. Arthur C. Ellings, "Sidewinder From the Production Viewpoint," NOTS 2068, 42–44
83. Tierney, S-224, 92.
84. *Rocketeer*, 19 Oct 1956, 1.
85. "Views of the Ex-Insider. The Mongol Horde," *News and Views*, Nov 1967, 11.
86. Younkin, S-183, 28.
87. S-181, 35.

Chapter 16

1. Memo A2-13 RFJ:je Ser AC-4, 4 Apr 1949, "Modification of Danger Areas over China Lake Aerial Gunnery Range and Trona Pilotless Aircraft Bombing and Aerial Gunnery Range; Request for," Navy Member, Headquarters, Commander, Naval Air Bases, 11ND, to Secretary, Los Angeles Regional Airspace Committee, Civil Aeronautics Authority.
2. Research Board minutes, 28 Sep 1953, 1–2; and 1, Feb 1954, 2.
3. *Rocketeer*, 23 Dec 1954, 5.
4. Because of the longer ranges needed for testing missiles, NOTS also began efforts in 1952 to expand its northern borders into Saline Valley. The proposed acquisition was complicated, with numerous governmental and private interests involved. After strenuous objections from Inyo County and private interests, Navy officials withdrew their support for the acquisition, citing studies that "the U.S. Naval Ordnance Test Station can continue to perform its assigned missions with existing facilities." Memo Op-516/rk, 9 Mar 1954, "Saline Valley area; status of," Op-516/rk to Op-51B via Op-512; memo, Op-445/paf Ser 589P44, 22 Apr 1959, "Proposed Saline Valley aerial Gunnery Range land acquisition; requirement for, "CNO to Chief, Bureau of Yards and Docks; *Indian Wells Valley Independent*, 1 Sep 1960.
5. Research Board minutes, 11 Jan 1955, 3; *Rocketeer*, 14 Jan 1955, 1–5.
6. *Rocketeer*, 21 Jan 1955, 2.
7. J. Tracey, "Moveback to New G-1 Range Facilities Marks 10 Years of Progress," *Rocketeer*, Feb 1955 special issue, 8.
8. "Newly Established Drone Unit at Armitage Field To Launch First Pilotless Aircraft Flight Today," *Rocketeer*, 6 Aug 1954, 8; "New Drone Unit Established in AOD To Provide Aerial Targets for Missile-Firing Test Projects," *Rocketeer*, 25 Mar 1955, 6.
9. McClung, S-198C, 25–26.
10. Highberg, S-121, 26; Bowen, S-175, 52.
11. In June 1958 Seeley was granted a patent on the tow target (*Rocketeer*, 3 Jul 1958, 1).
12. "Tow Target Developments at China Lake Enable Aerial Gunnery Tests at More Than 400 Knots," *Rocketeer*, 18 Jun 1954, 6.
13. Lakin, S-195, 5 Oct 1991, 9. The plywood in each target reportedly cost $15.
14. Memo 35/NEW:bjs J29 Ser 862, 20 Jan 1955, "NOTS Developed High Speed Tow Target; information concerning," Commander, NOTS, to Commander, Air Research and

Development Command, via Chief, BuOrd (RG38); Ward notes, 15 Mar 1960, for talk to AOD all-hands meeting (WPR).

15. Memo 3011/RAB:wa A1-1/S-23 Ser 21, 17 May 1957, "IR Target Source for SIDEWINDER; history and recommendations for extended use of," Head, Sidewinder Branch, to Head, Project Engineering Div.

16. The First Army Guided Missile Battalion began a six-year association with NOTS in July 1946. When NAMTC was established in October 1946, most of the battalion moved to Point Mugu, leaving Battery C at NOTS until June 1952, when the 25-man unit moved to Fort Bliss en route to the White Sands Proving Ground. *Rocketeer,* 18 Jun 1952, 8.

17. BuOrd memo, Es2a-GJO:rl S78-1(126), 25 Feb 1954, "U.S. Naval Guided Missile Unit No. 61, Inyokern, California; Mission of," Chief, BuOrd, to Officer in Charge, U.S. Naval Guided Missile Unit No. 61, NOTS.

18. Tierney, S-224, 41.

19. Remarks at Community Dinner, Sidewinder 50th Anniversary, Kerr McGee Community Center, Ridgecrest, 1 Nov 2002. When Tierney left NOTS in June 1957, his replacement was Commander Selden N. May, who had been the NAF administrative officer since October 1956. "He already knew when he relieved me that it was in the works that the unit was going to be disestablished," said Tierney. In July 1959 the unit was disestablished and the officers and men of GMU-61 were absorbed into NAF.

20. *Rocketeer,* 1 Mar 1957, 4; 22 Mar 1957, 4; and 17 May 1958, 3.

21. OPNAV Report 5750-5, Encl. 2, Command History of the Marine Barracks, NOTS, 17 Jul 1945 –31 Dec 1958, 1–2 (Minor Research Package #12).

22. Memo WEW:ced P16-1/1 Ser 054, 11 May 1954, "Activation of First TERRIER SAM Battalion, USMC; recommendations concerning," CO, First Provisional Marine Guided Missile Battalion, NOTS, to Commandant of the Marine Corps.

23. Research Board minutes, 25 May 1954, 2.

24. Memo, 7 Feb 1955, "Designation of Unit; change of," Commanding Officer, First Terrier Surface-to-Air Missile Battalion, NOTS, to CNO (Op-51) (RG38); *Rocketeer,* 11 Feb 1955, 1.

25. Research Board minutes, 14 Jun 1955, 4. A member of the BuOrd evaluation teams for both Terrier and Sidewinder, Caltech graduate Ashbrook was head of the Test Department's Electronic Development Branch. Before he arrived at NOTS in 1946, he had spent four years on the staff of MIT's Radiation Laboratory. He was a specialist in the development of microwave radar receiving equipment and counter-countermeasure techniques, applying that expertise at China Lake to the development and operation of the first radio-link timing system used on the ground ranges.

26. Memo A03H-mrh, 26 Oct 1955, "U.S. Marine Corps TERRIER Guided Missile Personnel at NOTS during Fiscal Year 1956 and 1957, tentative plans for," Commandant, Marine Corps, to Commander, NOTS, quoted in Station Journal, 1–30 Nov 1955, 4.

27. Memo A03H-mrh, 14 Mar 1956, "Marine Corps Guided Missile Test Unit (MCGMTU), establishment of," Commandant of the Marine Corps, to Commanding Officer, Marine Barracks, NOTS; "Marines Say 'Farewell' to China Lake," *Rocketeer*, 20 Apr 1956, 8.

28. On 29 April 1994, VX-5 and VX-4 from Point Mugu were consolidated into Air Test and Evaluation Squadron Nine, VX-9, stationed at China Lake. *Rocketeer*, 5 May 1994, 3

29. *Rocketeer*, 23 May 1991, 3.

30. Research Board minutes, 2 Feb 1953, 6–9.

31. Memo VX-5/RJS/jn File No. A1 Ser 630, 29 Aug 1952, "Squadron Space and Material Requirements," Commanding Officer, VX-5, Moffett Field, to Commander, NOTS.

32. Memo 14 Ser 01342, 1 Oct 1952, "Comments on Basing Fleet Units at the Naval Ordnance Test Station," Commander, NOTS, to Chief, BuOrd.
33. Research Board minutes, 15 Nov 1954, 3.
34. Ltr, 30 Aug 1954, "Van" to Dr. Ward (WPR).
35. Unattributed NOTS paper, 9 Jun 1955, "Naval Ordnance Test Station Comments on the Conclusions and Recommendations from the report of The Panel to Examine Mission and Tasks of the Naval Ordnance Test Station," 8–9.
36. Station Journal, 1-30 Apr 1956, 8–9; *Rocketeer*, 13 Jul 1956, 1. Naval Academy graduate Gilkeson distinguished himself as a naval aviator in both World War II and Korea.
37. "Special Weapon Delivery Perfected at C-Range," *Rocketeer*, 20 Sep 1957, 4.
38. NAF scrapbook.
39. Transcript of Aviation Ordnance Dept. Skits and Songs, Rehearsal and Party, Dec 1952. Among those commending Heflin for his support were several fighter squadrons and the Naval Air Special Weapons Facility, Kirtland Air Force Base. A 1941 graduate of Oklahoma University and a World War II bomb-disposal specialist and battery officer, Heflin was the test scheduling officer at Harvey Field, Inyokern, June–December 1945. After he left the service, Heflin became a NOTS civil servant. By 1957 he was NAF's sole link to those first days at Harvey Field.
40. John Di Pol review comments. Kleine arrived at China Lake as a young naval officer assigned to the Navy-Caltech rocket program and transferred to NOTS civil service after World War II. He retired in 1976 after 32 years of combined military and civilian service, then began applying his bias for action to community service. His idea of a central place where people could get answers to questions about the community resulted in the Information Center of Indian Wells Valley, formed in January 1993 and staffed entirely by volunteers.

Chapter 17

1. Wilson, S-96, 40–41.
2. *Rocketeer*, 6 Sep 1957, 1; "Biography/NWC Commanding Officers #9."
3. Wilcox, S-107, 2.
4. Swenson, et al., *This New Ocean*, 20; Baar and Howard, *Polaris!* 55.
5. *Rocketeer*, 27 Jan 1956, 2.
6. York, *Race to Oblivion*, 104.
7. Gavin, *War and Peace in the Space Age*, 14–17.
8. Joseph and Stewart Alsop, *The Reporter's Trade*, Reynal & Co., New York, 1958, 354–355.
9. Union Calendar No. 34, House Report, No. 67, *A Chronology of Missile and Astronautic Events. Report of the Committee on Science and Astronautics*, U.S. House of Representatives, 87th Congress, 1st session, Government Printing Office, Washington, DC, 1961, 29–32.
10. "Device Is 8 Times Heavier Than One Planned by U.S.," *New York Times*, 4 Oct 1957, 1, 3.
11. In "Sputnik and American Public Opinion" (*Columbia University Forum*, Winter 1957, 15–21), Samuel Lubell examined the reactions of citizens in New York and New Jersey; he found these views strikingly similar to those of the President.
12. *New York Times*, 6 Oct 1957, quoted in Gavin, 18.
13. Lieutenant Colonel A. Bulatov, "Pentagon Astir," *Sovetsky Flot*, translated by Northern Translations Service, "Truth About Rockets, Missiles and Satellites," Oct 1957, 12–13 (RG38).
14. *Rocketeer*, 11 Oct 1957, 1.

15. Video presentation, "Secret City: A History of the Navy at China Lake."
16. LaV McLean taped recollections, Historical Society, 14.
17. S-197, 10–11.
18. Saint-Amand, S-120, 3.
19. NOTS msg 082326Z to Naval Research Laboratory, quoted in Station Journal, 1 Oct–31 Oct 1957, 3.
20. "China Lakers played role in birth of satellite age," *News Review*, Ridgecrest, 15 Oct 1997, A10.
21. *Rocketeer*, 8 Nov 1957, 2; 13 Dec 1957, 2.
22. "Johnson Vows to Push Congress on Satellites," *New York Times*, 19 Oct 1957, 9.
23. Testimony of Dr. Wernher von Braun, *Hearings Before the Preparedness Investigating Subcommittee of the Committee on Armed Services, Inquiry Into Satellite and Missile Programs*, U.S. Senate, 85th Congress, 1st and 2nd Sessions, Part 1, 25 Nov 1957–23 Jan 1958, Government Printing Office, Washington, 1958, 618.
24. Killian, *Sputnik, Scientists, and Eisenhower.* 119.
25. Eisenhower, *The White House Years. Waging Peace 1956–1961*, 256–257.
26. *Rocketeer*, 7 Feb 1958, 1–2; 14 Feb 1958, 1. In addition to two other JPL stations in this country (one at Temple City, Utah, and one at San Diego), Microlock stations were located at Antiqua Island, Nigeria, and the Philippine Islands.
27. S-220, 27. Boyd came to NOTS in 1951 after receiving his A.A. in electrical technology from San Bernardino Valley College. For his first six years at China Lake he worked as an electronics technician, earning his B.S. in electrical engineering by passing a Civil Service Commission equivalency exam in 1957. He subsequently earned his M.P.A. and rose to become head of the Range Department, receiving the L.T.E. Thompson Award in 1988 for numerous technical accomplishments. He retired in 1994 and died in 2006.
28. Research Board minutes, 25 Feb 1958, 3–4.
29. Telephone call summary, 10 Oct 1957, "Satellite and POLARIS," McLean to Wilcox.
30. Riggs, S-136, 102.
31. Advisory Board minutes, 14–16 Nov 1957, 17-3 and -4. Board members in attendance were Robert L. Biggers, Rear Admiral C. M. Bolster, USN (Ret), Dr. Norris E. Bradbury, W. Kenneth Davis, Henry Dreyfuss, Edward H. Heinemann, Professor Kenneth S. Pitzer, Dr. William Shockley, Carleton Shugg, Dr. H. Guyford Stever, and Dr. L.T.E. Thompson. Also in attendance were Rear Admiral Frederic S. Withington, Chief of BuOrd; Rear Admiral Robert E. Dixon, Chief of the Bureau of Aeronautics; and Captain Edwin B. Hooper, BuOrd Assistant for Nuclear Applications.
32. AdPub 107, Encl. 1, *Basic Information on U.S. Naval Ordnance Test Station China Lake, California, In Reply to Secretary McNamara's Task No. 97*, Aug 1961, 37.
33. Dr. William H. Pickering, director of JPL, apparently originated this term, which he applied to a similar concept suggested in 1945 by Commander Harvey Hall, special scientific assistant to the head of the Radar Section, BuAer. The concept was subsequently incorporated into JPL's engineering studies for a high-altitude test vehicle, described by R. Cargill Hall in "Earth Satellites, a First Look by the United States Navy in the 1940's," 13–14.
34. NOTS 2000, Rev. 1, *Status Report on the Naval Observational Television Satellite Project*, by Weapons Development Dept., 2 Apr 1958, Appendix I, "A Proposed Feasibility Study for a Naval Observational Television Satellite," prepared 18 Nov 1957, 101–105.
35. NOTS 2000, Rev. 1, 1.
36. Ruckner Naval Institute oral history, 304 (OA).
37. Woodworth, S-215, 75.
38. Research Board minutes, 17 May 1948, 2–3. The JP program had started at the Pasadena

Annex in 1948 and had rapidly been adopted at China Lake.

39. Moore, S-185, 1–2, 5.

40. Informal Research Pkg #6, 1–2.

41. Harold Metcalf review comments, 8 Sep 1998.

42. An excellent discussion of this reorganization may be found in York and Greb, 13–25.

43. Booz, Allen R&D management study, summary, 53–54.

44. *Rocketeer*, 28 Feb 1958, 1.

45. Sewell review comments, Aug 1998. In later years, NOTSNIK became known as Project Pilot, the name attached to the NOTS film made of the chalk talk.

46. S-196, 14.

47. S-107, 4.

48. IDP 1092, *A Review of the Management of the NOTS I Project,* by Eugene Walton, Central Staff, Aug 1960, 3.

49. Comments to the author, 9 Apr 1999.

50. AdPub 107, Encl. 1, 39.

51. Column, "The Periscope," *Newsweek*, 4 Aug 1958, 7.

52. CHINFO msg, 211736Z to NOTS China Lake, 21 Aug 1958. In review comments, Doig said that China Lake's work on the Argus project, satellite killers, and spy satellites was responsible for keeping the pioneering NOTSNIK contributions to the space race secret for more than 30 years.

53. Booz, Allen R&D management study, summary, 27; DNL-T24-80, 6 (NL).

54. Booz, Allen R&D management study, 54–56.

55. E-mail, S. Joel Premselaar to the author, 26 Sep 2004. "Interestingly, at the debriefings none of the chase pilots could agree 100% with the others as to what they saw," Premselaar commented.

56. NOTSNIK participants' interview by St. George, 9; Informal Research Pkg #6.

57. S-107, 7.

58. Informal Research Pkg #6, memo 4003/FHK:jb Reg 40-073, 18 Mar 1960, Assistant Head, Weapons Development Dept., to distribution, Encl. 1, "Astronautics Test Schedule. Summary of NOTS I Test Vehicle."

59. The three satellites incorporating radiation monitors for Project Argus were launched on 25, 26, and 28 August 1958. Sewell, "NOTSNIK," *The China Laker*, Winter 2004, 1, 9.

60. S-196, 63.

61. Bowen, S-175, 32; Informal Research Pkg, #6.

62. Ralph Vartabedian, "One Last Transmission From Satellite Old-Timers," *Los Angeles Times*, 2 Oct 1994, D6.

Chapter 18

1. Wilson, S-96, 41; Ward, S-94, 19.

2. Research Board minutes, 9 Jul 1957, 3; and 23 Jul 1957, 2.

3. Paper TS 58-119, Nov 1957, "Considerations for the NOTS Advisory Board."

4. Memo 01/WBM:gs Reg No. 8 Ser 0163, 6 Feb 1958, "Research and Development Management System; program planning and review," Commander, NOTS (McLean), to Chief, BuOrd (Rex), (McLPR).

5. Research Board minutes, 9 Sep 1958, 5.

6. Memo 35/NEW:ls, 11 Feb 1965, "CAPT Moran," Ward to K. H. Robinson. The Corvus air-to-surface antiradar weapon, canceled in 1960, was a descendent of the pioneering Moth and Battu (Bat modified for antiradar use) of the World War II era. Fred Alpers was a leading

Corvus developer at the Naval Ordnance Laboratory Corona (NOLC). Alpers, who had a master's degree from Yale University, originated many technical concepts during work at the MIT Radiation Laboratory and the Missile Development Division of the National Bureau of Standards. With creation of NOLC in 1953, Alpers became head of the Guidance Division of the NOLC Missile Systems Department. The Corona lab closed in 1967, with the work reassigned to China Lake. Alpers came to the desert in 1971 as an employee of the Fuze Department. He retired in 1981 and died in 2006.

7. Smith, *Looking Ahead From Way Back*, 55.

8. Jagiello, S-168, 29–30.

9. According to Leroy Riggs, S-136, 59–60, his wife Ditty (Marilyn) came up for the name of the missile after consulting her bird book.

10. Riggs, S-136, 8–9.

11. Knemeyer S-200, 37.

12. In review comments, Doig noted that the SCR-584 was the perfect target since Russian copies of that radar system were a major radar threat during the Korean conflict.

13. Russell review comments. In 1963 Russell became head of the Missile Branch in the Guided Missile Division. Two years later he became head of the division, and by 1974 he was head of the Electronic Warfare Department. He became head of the Engineering Department in 1978 and retired in 1994.

14. Knemeyer, "Shrike's Forgotten Lessons," *The China Laker*, Fall 2004, 12; NOTS memo 35/NEW:ls, 11 Feb 1965, "CAPT Moran," Ward to Robinson.

15. Video production, "The Origins of ARM. Defense Suppression and the Shrike Antiradar Missile."

16. Rocketeer, 24 Jan 1958, 1; *Indian Wells Valley Independent and Times-Herald*, 25 Apr 1957, A-1.

17. S-225, 64–65.

18. Patton, S-179, 60–61, describes some of McLean's adventures with wet suits.

19. Cozzens, S-126, 3–4. Cozzens arrived at China Lake in March 1951, an early graduate from the University of Utah. After completion of his JP tours, he began work in the Design and Production Department. His career grew along with what became the Engineering Department, and by the time he retired in 1988, he was the associate department head. He developed a towering reputation, both for his accomplishments and for his sometimes curmudgeonly workplace relationships. He died in August 1998.

20. Steel, who began work in UOD's Propulsion Division in 1949, had both bachelor's and master's degrees in mechanical engineering from Case Institute, as well as a master's in science from MIT, earned during his Sloan Fellowship year. His diverse experience included running a construction business, serving four years in the Navy during World War II, working for aircraft companies, and teaching marine engineering at the Naval Academy. His work at the Pasadena Annex was primarily in propulsion systems. *Rocketeer*, 21 May 1954, 3; 26 Nov 1954, 3. For insights into Steel's leadership style, see Cox and Nathan, S-190, 39-40.

21. Research Board minutes, 22 May 1956, 4.

22. *Rocketeer*, 11 Jul 1958, 3. In 1961 Wilcox received the L.T.E. Thompson Award, the station's highest, for his leadership of the ASROC program. See Appendix B for the citation.

23. S-174, 34.

24. Douglas J. Wilcox, "Working With NOTS Contractors: Criteria for Mutual Understanding," *News and Views*, Jun 1966, 2, 4.

25. Wilson, S-96, 63–64.

26. Crawford, S-171, 2; Woodworth, S-215, 81.

27. Crawford, S-171, 39–44.

28. Wilcox, DNL-T5-78, 14 (NL).
29. Administrative Board minutes, 21 Oct 1957, 1.
30. Wilcox, S-103, 5
31. S-171, 23–24.
32. S-215, 20.
33. S-215, 23. Crawford, a born tinkerer, started his advanced education at the Coast Guard Academy. After discovering that the life of a Coast Guard officer didn't suit him, he obtained a degree in electrical engineering from the University of California at Berkeley. He arrived on the desert in 1950 and subsequently rose to become head of Development Division 1 in the Aviation Ordnance Department, head of the Air-to-Surface Systems Division in the Air Weapons Department, and head of the Radio Frequency Division in the Weapons Department. He retired in 1994 and died in June 2005.
34. Former NWC Technical Director Burrell W. Hays told a meeting of the Historical Society of the Upper Mojave Desert (15 Sep 1998) that Woodworth was "probably the best design engineer the base had." Woodworth, who arrived in China Lake in 1952 after earning a degree in electrical engineering from South Dakota State University, was one of the first two recipients of the William B. McLean Award (along with McLean himself) for outstanding creativity as evidenced by the significance of the patents received. When Woodworth received the McLean Award again in 1976, the *Rocketeer*, 24 Sep 1976, 5, commented that he was the only employee to have earned the award for a second time. Woodworth retired in 1991 and died in June 2007.
35. Memo 3511/JAC:WHW:ady Ser 6, 28 Jan 1957, "TV Guided Missile," Crawford and Woodworth to Ward.
36. S-171, 17.
37. S-215, 24. The transistor, invented by Bell Telephone Laboratories scientists William Shockley and Walter Brattain in 1948, existed mainly as a laboratory curiosity until the mid-1950s.
38. Ward, S-91, 6–7; Crawford, S-112, 12.
39. "In 1960, a Marine pilot from Cherry Point who had used the system came to China Lake to shake Mr. Glass's hand. To quote Mr. Glass, 'He almost squeezed my hand off,'" reports NAWC RM-26, 16.
40. McEwan review comments.
41. *Rocketeer*, 17 Oct 1958, 1.
42. Memo 4508/HMN:amd Reg 4532-45, 21 Jan 1960, "RAPEC I, Correspondence Files," Herbert M. Neuhaus to Richard Lucas; N. L. Rumpp, R. Zabelka, and B. Campbell, draft paper for *Bulletin of Ordnance Information*, 27 Dec 1957.
43. McEwan review comments.
44. NOSC TD 1940, *Fifty Years of Research and Development on Point Loma*, 53; Smith, S-177, 41.
45. Ltr, 01/WBM:rrn (0257), 13 Feb 1957, William B. McLean, Technical Director, NOTS, to Dr. E. S. Lamar, BuOrd (Req) (McLPR).
46. NOTS 1770, *Polaris Development Test Facilities San Clemente Island,* Underwater Ordnance Dept., 15 Jun 1957, 1–19; *Rocketeer*, 1 Jun 1956, 3.
47. *Rocketeer*, 6 Apr 1956, 3; and 16 Nov 1956, 3.
48. Memo AN9:VDM:vo 5750 Ser 8, 20 Jan 1966, "Ship's History; submission of," Commanding Officer, *Butternut* (AN 9) to Commander in Chief, U.S. Pacific Fleet, Encl. 1, "History of U.S.S. *Butternut* (AN-9) ex (YN-4)"; *Rocketeer,* 20 Jun 1958, 3.
49. Talkington, "NOTS, San Clemente Island," 92–101.
50. Campbell, S-174, 21. The other atmosphere tanks were in Minnesota and Germany.

51. The Fishhook tests were completed on schedule in 1959, just before the commissioning of *George Washington*, the first of the Navy's Polaris submarines.

52. S-177, 41–43. In the 1960s Smith sent funds to China Lake for construction of the huge Skytop solid rocket motor test facilities to facilitate testing of full-scale rocket motors.

53. Research Board minutes, 27 May 1958, 2.

54. "Newsmen Witness First Polaris Firing at San Clemente Island," *Rocketeer*, 27 Jun 1958, 1.

55. Eisenhower, *The White House Years*, 292–299.

56. Unidentified Nationalist Chinese fighter pilot, "Sting of the Sidewinder," in Ulanoff, *Fighter Pilot*, 421.

57. Tierney, S-224, 81.

58. Stroop, S-191, 18.

59. Moran in Westrum interview, 53–54.

60. Warren Smith, S-239, 4–7.

61. Wojecki, S-212, 13–14.

62. Information Report, Office of Naval Intelligence, Ser 32-S-58, 19 Sep 1958, Encl. 1, "Situation Report No. 8 of 12 Sep 1958"; Serial No. 38-S-58, 26 Sep 1958, Encl. 1, "Situation Report No. 14 of 19 Sep 1958."

63. Information Report, Office of Naval Intelligence, Serial No. 45-S-58, 25 Sep 1958, Encl. 1, "Situation Report No. 19 of 25 Sep 1958."

64. Chien was an honored guest at China Lake when the Naval Air Weapons Station and the U.S. Naval Museum of Armament and Technology celebrated Sidewinder's 50th anniversary on 1–3 Nov 2002. His comments come from a China Lake Museum Foundation video, "To the sea . . . a Sidewinder," as well as from remarks he made during the "Shooters Panel," presented 1 Nov 2001 at the China Lake Theater. The anonymous CAF pilot was quoted in "Sting of the Sidewinder," in Ulanoff, *Fighter Pilot*, 421–422.

65. S-224, 81–82.

66. S-196, 52–53.

67. *The White House Years*, 302–303. In his *Multicrises*, 239–240, historian Jonathan Trumbull Howe notes that the Communist blockade of the islands was eased significantly on 14 September by the use of armored amphibious tractors to transport supplies, including 8-inch howitzers, from ship to shore. He also cites the use of Sidewinder as making a significant contribution to the easing of a tense situation.

68. S-191, 59.

69. *Aviation Week*, 6 Oct 1958, 35; Associated Press clipping, "Sidewinder's in Big Demand by U.S. Allies," no newspaper or page information available.

70. S-210, 78.

Chapter 19

1. "Mission of a Weapons Development Center," speech given 8 May 1948, at the dedication ceremony for Michelson Laboratory (TPR).

2. NOTS 945, *Some Factors in Rocket Development*, by Dr. Emory L. Ellis, Meeting of the Rocket, Jato, & Guided Missile Committee, American Ordnance Assoc, 10 Oct 1954, 6.

3. Draft memo 14 /9-8-52, "Comments on Basing Fleet Units at the Naval Ordnance Test Station," Commander, NOTS, to Chief, BuOrd. Draft by Connolly.

4. McLean, "Sidewinder Design Concepts," presented at the Guided Missile Branch Conference, American Ordnance Assoc, China Lake, 15–16 Nov 1956 (CwPPR).

5. Ltr, 01/HGW:mci Ser 1961, 12 Apr 1973, H. G. Wilson to VAdm. William J. Moran,

Director, Research, Development, Test and Evaluation (NOP-098), 3. The NWC Wilson referred to was the Naval Weapons Center, successor organization to NOTS.

6. Mack, S-228, 24.

7. Research Board minutes, 15 May 1950, 7.

8. BA-1-75, 4 (NL).

9. Quoted in Riley, *"The Navy's Top Handyman,"* 35.

10. S-112, 69.

11. McLean speech, "Management and the Creative Scientist," included in RM-24, *Collected Speeches of Dr. William B. McLean.*

12. Sidewinder legacy panel, Sidewinder 50th Anniversary, China Lake Theater, 1 Nov 2002.

13. McLean speech, "Research and Development of Military Equipment," RM-24, 12.

14. Cone, S-210, 39.

15. Ltr, 18 Aug 1961, McLean to Mr. John Golden, in AdPub 107, Encl. 1, "Basic Information on U.S. Naval Ordnance Test Station China Lake, California. In Reply to Secretary McNamara's Task No. 97," Aug 1961, 1–2.

16. LaBerge, S-207, 5.

17. Hafstad speech, Station Theater, NOTS, 25 Jul 1949, 5 (TPR).

18. Ltr, 01/HGW:mci Ser 1961, 12 Apr 1973, 2.

19. S-226, 19–20.

20. S-200, 26.

21. S-194, 16–17.

22. "Chris Hinzo—he said 'I can do it,' then did," *News Review* Sidewinder 50th Anniversary section, 30 Oct 2002, 18.

23. Doig review comments; Di Pol, "Principles, tools, teamwork were keys to success," *News Review*, 30 Oct 2002, 25.

24. S-180, 12.

25. Ditty Riggs e-mail to the author, 9 Jan 2005.

26. S-207, 4–5.

27. S-191, 7.

28. "Wartime waymarks led young grad student home," *News Review*, 30 Oct 2002, 19.

29. Legacy panel, Sidewinder 50th Anniversary, 1 Nov 2002.

Bibliography

Archival and Special Collections

Archives, Naval Air Weapons Station, China Lake, CA

Administrative and technical papers, filed alphabetically by subject.

Administrative Board meeting minutes, 1949–1958.

Advisory Board meeting minutes, 1949–1958.

Research Board meeting minutes, 1948–1958.

Compilations

Biographical Information/NWC Commanding Officers.

Informal Research Package #5, Early Development of Television-Guided Missiles, compiled by Code 5313, April 1975.

Informal Research Package #6, The NOTS Project, compiled by Minchen Strang, Code 5313, April 1975.

Informal Research Package #7, History of the Development of Aircraft Fire Control Systems & Weapon Delivery Systems NOTS/NWC, compiled by Elizabeth Anderson, Code 5313, January 1973.

Minor Research Package #5, Summary of Station Background and Policy—Current Status and Planning for the Technical Program, U.S. Naval Ordnance Test Station Inyokern, CA, 20 March 1950.

Minor Research Package #6, Underwater Ordnance Dept. NOTS Pasadena, compiled by Code 5313, January 1975.

News and Views, collection of newsletters published by Management Div., Central Staff, in the late 1960s–mid 1970s.

The Rocketeer, files of the China Lake in-house weekly newspaper.

Station Journal, U.S. Naval Ordnance Test Station, China Lake, CA, April 1955–June 1958.

"U.S. Naval Air Facility History," Vol. 1, loose-leaf scrapbook of the history of the Naval Air Facility, China Lake (date unknown).

Inside-Distribution Papers and Reports

Ashworth, Rear Admiral F. L., USN. "Some Thoughts on Better Laboratory Management," Speech given at Second Conference on Military RDT&E, Quantico, VA, 8 January 1962.

Gerrard-Gough, J. D. "Super-forts at China Lake," January 1978.

Haubein, W. L. "Feasibility Studies of a Gas Generator for Launching the Polaris Missile," NOTS IDP 373, 15 January 1958.

Nickerson, McLean, Christensen and Associates. *A Study of Administrative Problems at U.S. Naval Ordnance Test Station, Inyokern, California*, Belmont, MA, Summer 1951.

Projectile Range Div.. "Informal VT Fuze Range Progress Report," Test Dept., U.S. Naval Ordnance Test Station, Inyokern, presented at 15 June 1954 conference, Naval Ordnance Laboratory, White Oak, MD.

______. *Randsburg Wash Activities Quarterly Progress Report 1 January to 30 March 1956*, U.S. Naval Ordnance Test Station.

Starnes Co. *Development History of the 2.75-Inch Folding-Fin Aircraft Rocket*, draft report, Chapters 3-11, 3 February 1954.

Walton, Eugene. "A Review of the Management of the NOTS I Project," Management Research Div., Central Staff, NOTS IDP 1092, August 1960.

Manuscripts

Draft History of the Technical Officer at the Naval Weapons Center, by Frances Matthews, Technical Information Dept., and Mary McIntire, Office of Finance and Management, Naval Weapons Center, October 1981.

NWC Retrievable Manuscript RM-1, *Salt Wells Pilot Plant Story 1945–1954*, by Kenneth H. Robinson for Technical Information Dept., Naval Weapons Center, July 1974.

NWC Retrievable Manuscript RM-3, *Technical History of the U.S. Naval Ordnance Test Station 1943–1953*, researched and written by Starnes Co., Pasadena, published in manuscript form by Technical Information Dept., Naval Weapons Center, December 1975.

NWC Retrievable Manuscript RM-6, *Development of the 5.0-Inch Liquid Propellant Aircraft Rocket (LAR) Model 502*, by Dean H. Couch, Propulsion Development Dept., Naval Weapons Center, March 1976.

NWC Retrievable Manuscript RM-13, *The Development History of the Walleye Weapon System*, by G. R. Wallace, prepared for the Naval Weapons Center by Systems Consultants Incorporated under Contract N00123-76-0340, Naval Weapons Center, 20 September 1977.

NWC Retrievable Manuscript RM-17, Vol. 1, *NOTS-NWC Code Directories, Volume 1 1949–1965*, Technical Information Dept., Naval Weapons Center, January 1982.

NWC Retrievable Manuscript RM-17, Vol. 2. *NOTS-NWC Code Directories, Volume 1 1965–1980*, Technical Information Dept., Naval Weapons Center, August 1982.

NWC Retrievable Manuscript RM 22, *The NWC Explosives Program History and Analysis. Volume I: The History*, by Taylor B. Joyner, Engineering Sciences Div., Naval Weapons Center, March 1986.

NAWC Retrievable Manuscript RM-24, *Collected Speeches of Dr. William B. McLean*, Technical Information Dept., Naval Air Warfare Center Weapons Div., September 1993. McLean's speech, "The Sidewinder Missile Program," is also Chapter 15 in *Science, Technology, and Management* by Fremont E. Kast and James E. Rosenzweig. New York: McGraw Hill, 1962.

NAWC Retrievable Manuscript RM-26, *China Lake Machine Shops: 50 Years of Service to the Fleet November 1943–November 1993*, Technical Information Dept., Naval Air Warfare Center Weapons Div., September 1994.

"Reminiscences and Reflections Regarding the Sidewinder and Its Creator, Dr. William B. McLean," installments SW-1–SW-4, by Dr. Howard A. Wilcox, November 1986.

Sidewinder History (Manuscript), by David Rugg, prepared from the files of the Sidewinder Program Office, 1971–1974.

Oral Histories

NOTSNIK participants: Crill Maples, Robert G. S. "Bud" Sewell, Fred Ashbrook, Leroy Marquardt. Interview by Frank St. George, 15 March 1991.

S-1. Dr. L.T.E. Thompson. Interview by Albert B. Christman, 6, 7 November 1965.

S-15. Dr. L.T.E. Thompson. Interview by Albert B. Christman, May 1966.

S-21. Dr. L.T.E. Thompson. Interview by Albert B. Christman, 5 November 1966.

S-33. Commander John Richmond, USN (Ret). Interview by Albert B. Christman, January 1967.

S-34. Captain John I. Hardy, USN. Interview by Albert B. Christman, 13 February 1967.

S-42. Lieutenant General Leslie R. Groves, U.S. Army (Ret). Interview by Albert B. Christman, August 1967.

S-52. L.T.E. Thompson. Interview by Albert B. Christman, November 1967.

S-77. Dr. and Mrs. Emory L. Ellis. Interview by Albert B. Christman, 23 February 1971.

S-88. Dr. William B. McLean. Interview by Albert B. Christman, 16 November 1973.

S-94. Dr. Newton E. Ward. Interview by Albert B. Christman, 23 October 1974.

S-95. Dr. Hugh Hunter. Interview by Elizabeth Babcock, 30 May 1975.

S-97. Dr. William B. McLean. Interview by Albert B. Christman, July 1975.

S-99. James H. Jennison. Interview by J. D. Gerrard-Gough, 23 October 1975.

S-102. Dr. Arthur H. Warner. Interview by J. D. Gerrard-Gough, 11 December 1975.

S-106. Robert G. S. Sewell. Interview by Minchen Strang, 26 August 1975.

S-108. Dr. Gilbert Plain. Interview by Elizabeth Babcock, 9 December 1975.

S-111. Dr. James H. Wiegand, Interview by Michelle Ballenger, August 1977.

S-112. Aviation Ordnance Dept. Group: Dr. Thomas S. Amlie, Dr. W. Frank Cartwright, Jack A Crawford, Earl J. Donaldson, J. Raymond Schreiber, Charles P. Smith, Dr. Newton E. Ward, Dr. Howard A. Wilcox, Haskell G. Wilson. Interview by William F. Wright, 14 March 1980.

S-113. LaVerne McLean. Interview by William F. Wright, 18 March 1980.

S-120. Dr. Pierre Saint-Amand. Interview by Leroy L. Doig III, 27 March 1981.

S-121. Dr. Ivar E. Highberg. Interview by Leroy L. Doig III, 1 April 1981.

S-122. Lee E. Lakin. Interview by Andrew Kilikauskaus, 17 February 1981.

S-136. Leroy Riggs. Interview by Leroy L. Doig III, 18–19 June 1982.

S-141. Frederick C. Alpers. Interview by Leroy L. Doig III, 16 November 1982.

S-167. Vice Admiral John T. Hayward. Interview by Leroy L. Doig III, 14 October 1987.

S-168. Leonard T. (Lee) Jagiello. Interview by Leroy L. Doig III, 15 January 1988.

S-171. Jack Crawford. Interview by Elizabeth Babcock, 20 November 1988.

S-172. I. Bruce Wertenberger. Interview by Elizabeth Babcock, 6 December 1988.

S-174. Jim Campbell. Interview by Elizabeth Babcock, 25 January 1989.

S-175. James A. Bowen. Interview by Elizabeth Babcock, 14 April 1989.

S-177. Vice Admiral Levering and Mrs. Beulah "Boots" Smith. Interview by Elizabeth Babcock and Leroy L. Doig III, 15 June 1989.

S-178. Dr. Walter B. LaBerge. Interview by Elizabeth Babcock, 1 September 1989.

S-179. Harold H. Patton. Interview by Elizabeth Babcock, 4 September 1989

S-180. John M. Boyle. Interview by Elizabeth Babcock, 31 August 1989.

S-181. Ted and Eleanor Lotee. Interview by William R. Blanc, 13 March 1990.

S-186. LeRoy Jackson. Interview by Elizabeth Babcock, 16 November 1990.

S-188. Rod McClung. Interview by Elizabeth Babcock, 22 March 1991.

S-191. Vice Admiral Paul D. Stroop, USN (Ret.). Interview by Elizabeth Babcock and Leroy L. Doig III, 11 June 1991.

S-194. Dr. W. F. "Frank" Cartwright. Interview by Elizabeth Babcock and Dr. Ron Westrum, 28 August 1991.

S-195. John Di Pol, Lee Lakin, William Ward, and Bruce Wertenberger. Interview by Frank St. George, 5 October 1991.

S-196. Dr. Howard A. Wilcox. Interview by Elizabeth Babcock, 22 November 1991.

S-197. Haskell G. and Jane Wilson. Interview by Elizabeth Babcock, 23 October 1991.

S-198A. Francis C. "Frank" Wentink. Interview by David Rugg, 17 November 1970.

S-198B. Edwin G. Swann, Jr. Interview by David Rugg, 12 January 1971.

S-198C. Roderick M. McClung and David Simmons. Interview by David Rugg, week of 12 January 1971.

S-198D. Peter F. Nicol. Interview by David Rugg, week of 12 January 1971.

S-198E. Anne Nancy Carter. Interview by David Rugg, week of 12 January 1971.

S-198F. Lawrence W. Nichols. Interview by David Rugg, week of 12 January 1971.

S-199. Dr. Thomas S. Amlie. Interview by Elizabeth Babcock, William R. Blanc, and Mark Pahuta, 1 June 1992.

S-200. Franklin H. Knemeyer. Interview by Elizabeth Babcock, Leroy L. Doig III, and Mark Pahuta, 20 November and 13 December 1991.

S-201. Vice Admiral Levering and Mrs. Beulah "Boots" Smith. Interview by Elizabeth Babcock and Mark Pahuta, 24 October 1991.

S-202. Jim McLane. Interview by Elizabeth Babcock, Leroy L. Doig III, and Mark Pahuta, 17 January 1992.

S-203. Dr. Emory L. and Marion Ellis. Interview by Elizabeth Babcock, Leroy L. Doig III, and Mark Pahuta, 25 February and 2 April 1992.

S-204. Cecilia A. "Tina" Knemeyer. Interview by Elizabeth Babcock and Mark Pahuta, 20 February 1992.

S-206. Former WAVES: Hazel Coleman, Joan Deffes, Rose Gonzales, and Terry Wiruth. Interviews by Elizabeth Babcock and Mark Pahuta, 12 March 1992.

S-210. NOTS South Interviews: Lois Allan, John M. Boyle, Commander Wade Cone, Russell O. Huse, LaV McLean, Harold H. "Pat" Patton. Interviews by Elizabeth Babcock and Leroy L. Doig III, 10 June 1992.

S-211. Dr. Newton E. and Maryon Ward. Interview by Elizabeth Babcock, Leroy L. Doig III, and Mark Pahuta, 11 June 1992.

S-212. Joseph E. Wojecki. Interview by Elizabeth Babcock and Mark Pahuta, 10 July 1992.

S-214. Don R. Yockey, Interview by Elizabeth Babcock, William R. Blanc, and Mark Pahuta, 11 August 1992.

S-220. Richard V. Boyd. Interview by Elizabeth Babcock, William R. Blanc, Leroy L. Doig III, and Mark Pahuta, 19 November and 9 December 1992.

S-223. George Hucek. Interview by Elizabeth Babcock and Mark Pahuta, 4 February 1993.

S-225. Peter and Polly Nicol. Interview by Elizabeth Babcock, William R. Blanc, Leroy L. Doig III, and Mark Pahuta, 31 March 1993.

S-226. Vice Admiral Frederick L. Ashworth, Interview by Elizabeth Babcock, William R. Blanc, Leroy L. Doig III, and Mark Pahuta, 16-17 April 1993.

S-233. Guy C. Throner. Interview by Jill Guinn, 24 August 1994.

S-240C. Roundtable Discussion With Captain Thomas F. Pollock, USN (Ret). Other participants: Scott O'Neil, Robert G. S. "Bud" Sewell, Phil G. Arnold, Bill E. Camp, Clifford H. Anderson, Franklin H. Knemeyer and Richard J. "Dick" DeMarco, 24 January 1997.

Taped recollections of LaV McLean. Interview by Billie Hise, Historical Society of the Upper Mojave Desert, 20 September 1988.

Personal Papers

Papers of Dr. W. F. "Frank" Cartwright. A select collection of significant Sidewinder documents.

Papers of Lieutenant (later Rear Admiral) Thomas J. Christman. Sidewinder papers marked with "C" to show their historical significance.

Papers of Dr. William B. McLean.

Papers of Dr. L.T.E. Thompson.

Papers of Dr. Newton E. Ward.

Video Productions

"East of Eaton: The Story of the China Lake Propulsion Laboratories." Produced by China Lake Museum Foundation, 1995, 38 minutes.

"The Origins of ARM." Produced by China Lake Museum Foundation, October 2004, 75 minutes.

"Secret City: A History of the Navy at China Lake." Produced by China Lake Video Projects Branch (distributed by China Lake Museum Foundation), November 1993, 194 minutes.

"To the sea . . . a Sidewinder." Produced by China Lake Museum Foundation, November 1992, 67 minutes.

Washington National Records Center, Suitland, MD

Record Group 38, "Historical records of the Chief of Naval Operations Atomic Energy Division and Guided Missile Division for the period 1943–1961."

Operational Archives Branch, Naval Historical Center, Washington, DC

Files of *Naval Aviation Confidential Bulletin*, CONAVAER-00-75-500, Office of CNO and BuAer. Numerous articles on NOTS projects, 1948–1952.

Post 1 January 1946 Command File.

Oral Histories

Reminiscences of Rear Admiral Malcolm F. Schoeffel, U.S. Navy (Ret.) Interview by John T. Mason, Jr., U.S. Naval Institute, Annapolis, MD, September 1979.

Reminiscences of Vice Admiral Paul D. Stroop, U.S. Navy (Retired). Interview by U.S. Naval Institute, Annapolis, MD, 1970.

Director of Navy Laboratories Collection, David Taylor Research Center, Annapolis, MD

Oral Histories

BA-1-75. Dr. William B. McLean. Interview by Dr. Samuel Rothman and Mrs. Susan Frutkin, 12 December 1974.

BA-6. Rear Admiral E. A. Ruckner. Interview by Dr. Peter Bruton, September 1974.

BA-10. Vice Admiral Edwin B. Hooper. Interview by Captain Robert L. Hanson, Dr. Peter Bruton, and Mrs. Susan Frutkin, circa 1974.

BA-11. Vice Admiral John T. Hayward. Interview by Dr. Peter Bruton and Captain Robert L. Hanson, 9 October 1974.

DNL-T5-78. Douglas Wilcox. Interview by A. B. Christman, 13 March 1978.

DNL-T-23-80. Edith Laverne "LaV" McLean. Interview by Starla Hall, 17 June 1980.

DNL-T24-80. Dr. Herbert York. Interview by A. B. Christman, 24 September 1980.

NL-T25. Dr. Howard Wilcox. Interview by Starla Hall, September 1980.

Other Primary Sources

Rear Admiral Thomas J. Christman. Interview by Dr. Ron Westrum, 25 June 1993. Loaned by Dr. Westrum.

Vice Admiral William J. Moran and Leonard T. Jagiello. Interview by Dr. Ron Westrum, 18 July 1988. Loaned by Dr. Westrum.

Kenneth H. Robinson undated manuscript autobiography, "Copy 1 K.H.R.," loaned by his son, Charles W. Robinson.

Secondary Sources

Published Reports and Books

American Association of University Women, China Lake-Ridgecrest Branch. *Indian Wells Valley and Northern Mojave Desert Handbook*, 7th Edition. Salt Lake City: Seagull Press, 2002.

Armacost, Michael H. *The Politics of Weapon Innovation: The Thor-Jupiter Controversy.* New York, London: Columbia University Press, 1969.

Baar, James, and William E. Howard. *Polaris!* New York: Harcourt, Brace and Co., 1960.

Baldwin, Hanson W. *The Great Arms Race: A Comparison of U.S. and Soviet Power Today.* New York: Frederick A. Praeger, Inc., 1958.

Booz, Allen & Hamilton Inc. *Review of Navy R&D Management, 1946–1973.* Washington: Dept. of the Navy, 1 June 1976.

Borklund, Carl W. *Men of the Pentagon: From Forrestal to McNamara.* New York, London: Frederick A. Praeger, 1966.

Bottome, Edgar M. *The Missile Gap: A Study of the Formulation of Military and Political Policy.* Rutherford, Madison, Teaneck: Fairleigh Dickenson University Press, 1971.

Cagle, Malcolm W., and Frank A. Manson. *The Sea War in Korea.* Annapolis: Naval Institute Press, 1957.

Christman, Albert B. *History of the Naval Weapons Center, China Lake, California, Vol. 1. Sailors, Scientists, and Rockets: Origins of the Navy Rocket Program and of the Naval Ordnance Test Station, Inyokern.* Washington: Naval History Div., 1971.

_____. *Target Hiroshima: Deak Parsons and the Creation of the Atomic Bomb.* Annapolis: Naval Institute Press, 1998.

Cochrane, Rexmond C. *Measures for Progress: History of National Bureau of Standards.* Washington: Government Printing Office, 1966.

Coletta, Paolo E. *The United States Navy and Defense Unification, 1947–1953.* London and Toronto: University of Delaware Press, Associated University Presses, 1981.

Combs, Gary B., and Roberta S. Greenwood, editors. *A Cultural Resources Overview and Inventory Plan for the Naval Weapons Center, China Lake.* Pacific Palisades, CA: Greenwood and Associates, 1 November 1982.

Committee on the National Security Organization. *Report to the Commission on Organization of the Executive Branch of the Government by the Committee on the National Security Organization* (Hoover Commission Eberstadt Task Force). Washington: Government Printing Office, 15 November 1948.

Condit, Doris M. *History of the Office of the Secretary of Defense, Volume II: The Test of War, 1950–1953,* Washington: Historical Office, Office of the Secretary of Defense, 1988.

Davis, Vincent. *The Politics of Innovation: Patterns in Navy Cases.* Monograph Series in World Affairs, Vol. 4, Monograph No. 3. Denver: The Social Science Foundation and Graduate School of International Studies, University of Denver, 1966–1967.

Eisenhower, Dwight David. *The White House Years. Mandate for Change: 1953–1956.* Garden City: Doubleday & Co., Inc., 1963.

Endicott, John E., and Roy W. Stafford, Jr., eds. *American Defense Policy,* 4th Edition. Baltimore, London: Johns Hopkins University Press, 1977. Of particular interest is "Organizational Interests" by Morton H. Halperin, Priscilla Clapp, and Arnold Kantner, 214–215.

Field, James A., Jr. *History of United States Naval Operations: Korea.* Washington: Naval Historical Center, 1962.

Friedrich, Carl J., and Seymour E. Harris. *Public Policy: A Yearbook of the Graduate School of Public Administration, Harvard University 1963.* Vol. XII. Cambridge: Harvard Graduate School of Public Administration, 1963.

Gavin, Lieutenant General James M. *War and Peace in the Space Age.* New York: Harper & Row, 1958.

Gerrard-Gough, J. D., and Albert B. Christman. *History of the Naval Weapons Center, China Lake, California, Vol. 2. The Grand Experiment at Inyokern: Narrative of the Naval Ordnance Test Station During the Second World War and the Immediate Postwar Years.* Washington: Naval History Div.., 1978.

Gilpin, Robert, and Christopher Wright, eds. *Scientists and National Policy-Making.* New York, London: Columbia University Press, 1964.

Glatt, Evelyn. *The Demise of the Ballistics Division.* Berkeley: Institute of Governmental Studies, University of California, November 1964.

Golden, William T., ed. *Science and Technology Advice to the President, Congress, and Judiciary.* New York, Oxford: Pergamon Press, 1988.

Goodstein, Judith R. *Millikan's School: A History of the California Institute of Technology.* New York, London: W. W. Norton & Co., 1991.

Grant, Campbell, James W. Baird, and J. Kenneth Pringle. *Rock Drawings of the Coso Range.* Publication 4. China Lake: Maturango Press, 1968.

Hagan, Kenneth J., ed. *In Peace and War: Interpretations of American Naval History, 1775–1984.* Contributions in Military History, Number 41. Westport, CT, London: Greenwood Press, 1984.

Hallion, Richard P. *The Naval Air War in Korea.* Baltimore: The Nautical & Aviation Publishing Co. of America, 1986.

Hansen, Chuck. *U.S. Nuclear Weapons: The Secret History.* Arlington, Texas: AeroFax, Inc., 1988.

Harrington, Mark Raymond. *A Pinto Site at Little Lake, California.* Southwest Museum Papers Number Seventeen. Highland Park, CA: Southwest Museum, 1957.

Historical Society of the Upper Mojave Desert. *How It Was. Some Memories by Early Settlers of the Indian Wells Valley and Vicinity.* Ridgecrest, CA: Historical Society, 16 December 1994.

Hitch, Charles J., and Roland N. McKean. *The Economics of Defense in the Nuclear Age.* Cambridge: Harvard University Press, The Rand Corporation, R-346, March 1960.

Hone, Thomas C. *Power and Change: The Administrative History of the Office of the Chief of Naval Operations, 1946–1986.* Washington: Naval Historical Center, 1989.

Hooper, Vice Admiral Edwin B. *The Navy Department: Evolution and Fragmentation.* Washington: Naval Historical Foundation, 1978.

Hunley, J. D. *Preludes to U.S. Space-Launch Vehicle Technology: Goddard Rockets to Minuteman III.* Gainesville: University Press of Florida, 2008.

_____. *The Development of Propulsion Technology for U.S. Space Launch Vehicles, 1926–1991.* College Station : Texas A&M University Press, 2007.

Hurley, Colonel Alfred F., and Major Robert C. Erhart, eds. *Air Power and Warfare: Proceedings of the 8th Military History Symposium, United States Air Force Academy, 18–20 October 1978.* Washington: Office of Air Force History, Headquarters USAF and United States Air Force Academy, 1979. Papers consulted included John T. Greenwood, "The Emergence of the Postwar Strategic Air Force, 1945–1953," 215–244; Robert Perry, "The Interaction of Technology and Doctrine in the USAF," 386–401; and David Alan Rosenberg, "American Postwar Air Doctrine and Organization: The Navy Experience," 245–278.

Inter-Laboratory Committee on Facilities. *Facilities Review: West Coast Naval Laboratories.* China Lake: U.S. Naval Ordnance Test Station (TS 59-200), March 1959.

Isenberg, Michael T. *Shield of the Republic, Vol. I, 1945–1962. The United States Navy in an Era of Cold War and Violent Peace.* New York: St. Martin's Press, 1993.

Kahan, Jerome H. *Security in the Nuclear Age: Developing U.S. Strategic Arms Policy.* Washington: The Brookings Institution, 1975.

Killian, James R., Jr. *Sputnik, Scientists, and Eisenhower: A Memoir of the First Special Assistant to the President for Science and Technology.* Cambridge, London: MIT Press, 1977.

Kolodziej, Edward A. *The Uncommon Defense and Congress, 1945–1963.* Athens, OH: Ohio University Press, 1966.

Lofinck, Sewell "Pop." *Mojave Desert Ramblings. A Treasury of Unforgettable Recollections of a Desert Philosopher.* Publication 2. China Lake: Maturango Museum, November 1966.

McCollum, Kenneth G., ed. *Dahlgren.* Dahlgren: Naval Surface Weapons Center, June 1977.

Merrill, Captain Grayson, USN (Ret), ed. *Principles of Guided Missile Design: Dictionary of Guided Missiles and Space Flight.* Princeton: D. Van Nostrand Co., Inc., 1959.

NAVORD Report 1054, NOTS 174. *Facilities and Services Available for Free-Flight, Guided-Missile Tests at NOTS.* Inyokern: Measurements Div. Staff, Development Dept., U.S. Naval Ordnance Test Station, 22 November 1948.

NAVORD Report 1146, NOTS 210. *An Air-to-Air Target Seeker,* by D. T. Duckworth, Aviation Ordnance and Test Dept., Inyokern: U.S. Naval Ordnance Test Station, 11 March 1949.

NAVORD Report 1196, NOTS 252. *Aviation Ordnance Test Facilities,* by Staff, Aviation Ordnance Div., Aviation Ordnance and Test Dept.. Inyokern: U.S. Naval Ordnance Test Station, 21 October 1949.

NAVORD Report 1983, NOTS 565. *For Pilots Only: Pilots' Handbook of Operation for the Aircraft Fire-Control System Mark 16 Mod 2.* Inyokern, China Lake: U.S. Naval Ordnance Test Station, October 1952.

NAVORD Report 2041, NOTS 720. *Quarterly Bulletin: Activities in the Torpedo Program,* by Underwater Ordnance Dept., Inyokern: U.S. Naval Ordnance Test Station, 1 August 1953.

NAVORD Report 2056, NOTS 750. *Rocket Quarterly: Bulletin of Activities in the Rocket Program*. Vol. 1, No. 4. China Lake: U.S. Naval Ordnance Test Station, September 1953.

NAVORD Report 2059, NOTS 754. *For Pilots Only: Pilots' Handbook of Rocketry.* Inyokern, China Lake: U.S. Naval Ordnance Test Station, October 1953.

NAVORD Report 2062, NOTS 758. *Torpedo Quarterly: Bulletin of Activities in the Torpedo Programs*, by Underwater Ordnance Dept., China Lake: U.S. Naval Ordnance Test Station, 1 November 1953.

NAVORD Report 2085, NOTS 821. *Rocket Quarterly: Bulletin of Activities in the Rocket Program,* Vol. 2, No. 1. Inyokern, China Lake: U.S. Naval Ordnance Test Station, December 1953.

NAVORD Report 2086 NOTS 823. *Torpedo Quarterly: Bulletin of Activities in the Torpedo Program*, by Underwater Ordnance Dept., China Lake: U.S. Naval Ordnance Test Station, February 1954.

NAVORD Report 2097 NOTS 855, *Torpedo Quarterly: Bulletin of Activities in the Torpedo Program,* by Underwater Ordnance Dept., China Lake: U.S. Naval Ordnance Test Station, May 1954.

NAVORD Report 3334, NOTS 871. *Rocket Quarterly: Bulletin of Activities in the Rocket Program,* Vol. 2, No. 12. Inyokern, China Lake: U.S. Naval Ordnance Test Station, March 1954.

NAVORD Report 3344, NOTS 907. *For Pilots Only: Pilot's Handbook of Operation for Bomb Director Mark 3 Mod 4, Bomb Director Mark 3 Mod 5*. Inyokern, China Lake: U.S. Naval Ordnance Test Station, 2 June 1954.

NAVORD Report 3355, NOTS 919. *Rocket Quarterly: Bulletin of Activities in the Rocket Program*, Vol. 2, No. 3. Inyokern, China Lake: U.S. Naval Ordnance Test Station, June 1954.

NAVORD Report 3372 NOTS 951. *Torpedo Quarterly: Bulletin of Activities in the Torpedo Program*, by Underwater Ordnance Dept., China Lake: U.S. Naval Ordnance Test Station, November 1954.

NAVORD Report 3373, NOTS 952. *Preliminary Tests for Project Spot,* by D. G. Wilson, H. L. Anderson, J. Nicholson, Aviation Ordnance Dept., Inyokern, China Lake: U.S. Naval Ordnance Test Station, 14 October 1954.

NAVORD Report 3470, NOTS 1074. *Rocket Quarterly: Bulletin of Activities in the Rocket Program,* Vol. 3, No. 2. China Lake: U.S. Naval Ordnance Test Station, March 1955.

NAVORD Report 3497 NOTS 1121. *Torpedo Quarterly: Bulletin of Activities in the Torpedo Program*, by Underwater Ordnance Dept., China Lake: U.S. Naval Ordnance Test Station, May 1955.

NAVORD Report 3509, NOTS 1138. *Rocket Quarterly: Bulletin of Activities in the Rocket Program,* Vol. 3, No. 3. China Lake: U.S. Naval Ordnance Test Station, June 1955.

NAVORD Report 4888 NOTS 1184. *Torpedo Quarterly: Bulletin of Activities in the Torpedo Program*, by Underwater Ordnance Dept., China Lake: U.S. Naval Ordnance Test Station, August 1955.

NAVORD Report 4891, NOTS 1187. *Rocket Quarterly: Bulletin of Activities in the Rocket Program,* Vol. 3, No. 4. China Lake: U.S. Naval Ordnance Test Station, September 1955.

NAVORD Report 5035, NOTS 1380. *Torpedo Quarterly: Bulletin of Activities in the Torpedo Program*, by Underwater Ordnance Dept., China Lake: U.S. Naval Ordnance Test Station, February 1956.

NAVORD Report 5253 NOTS 1458. *Torpedo Quarterly: Bulletin of Activities in the Torpedo Program*, by Underwater Ordnance Dept., China Lake: U.S. Naval Ordnance Test Station, May 1956.

NAVORD Report 5288, NOTS 1513. *Rocket Quarterly: Bulletin of Activities in the Rocket Program,* Vol. 4, No. 1. China Lake: U.S. Naval Ordnance Test Station, December 1955.

NAVORD Report 5316, NOTS 1559. *Rocket Quarterly: Bulletin of Activities in the Rocket Program,* Vol. 4, No. 2. China Lake: U.S. Naval Ordnance Test Station, March 1956.

NAVORD Report 5396, NOTS 1649. *Rocket Quarterly: Bulletin of Activities in the Rocket Program*, Vol. 4, No. 3 and 4. China Lake: U.S. Naval Ordnance Test Station, June and September 1956.

NAVORD Report 5425, NOTS 1688. *Torpedo Quarterly: Bulletin of Activities in the Torpedo Program*, by Underwater Ordnance Dept., China Lake: U.S. Naval Ordnance Test Station, February 1957.

Navy-NOTS 11ND. *Summary of Major Accomplishments Fiscal Years 1944–1954,* prepared by Technical Div., Central Staff. Inyokern, China Lake: U.S. Naval Ordnance Test Station, 1 March 1954.

Navy NOTS 11ND. *Weapons for the United States Navy.* brochure prepared by Technical Information Dept.: China Lake: U.S. Naval Ordnance Test Station, 1 July 1957.

Neufeld, Jacob. *The Development of Ballistic Missiles in the United States Air Force, 1945–1960.* Washington: Office of Air Force History, U.S. Air Force, 1990.

Nichols, Major General Kenneth D., USA (Ret.). *The Road to Trinity.* New York: William Morrow and Co., Inc., 1987.

NAWCWPNS Ad Pub 019, *History of the Naval Weapons Evaluation Facility, Albuquerque, New Mexico, 1948–1993.* China Lake: Technical Information Dept., Naval Air Warfare Center Weapons Div., March 1993.

NOLC Report 471. *From Sky to Sea: Twenty Years of Guided Missile Development at NBS and NOLC Devoted Primarily to Air-to-Surface Missiles for the U.S. Navy.* Corona: Naval Ordnance Laboratory, October 1959.

NOSC TD 1940. *Fifty Years of Research and Development on Point Loma, 1940–1990.* San Diego: Naval Ocean Systems Center, September 1990.

NOTS 608. *First Steps to Rocketry,* by Hugo Meneghelli. Inyokern: U.S. Naval Ordnance Test Station, 22 December 1952.

NOTS 673. *Quarterly Bulletin: Activities in the Torpedo Program.* Inyokern: U.S. Naval Ordnance Test Station, 1 May 1953.

NOTS 752. Technical Progress Report. *The Supersonic Naval Ordnance Research Track (SNORT),* by James P. Judin. Inyokern, China Lake: U.S. Naval Ordnance Test Station, September 1953.

NOTS 989. *GIMLET 2.0-Inch Folding-Fin Aircraft Rocket.* Inyokern, China Lake: U.S. Naval Ordnance Test Station, 1 January 1955.

NOTS 1459. *Solid-Propellant Applied Research and Development at NOTS.* China Lake: Propellants and Explosives Dept., U.S. Naval Ordnance Test Station, 2 March 1956.

NOTS 1770. *Polaris Development Test Facilities San Clemente Island.* China Lake: Underwater Ordnance Dept., U.S. Naval Ordnance Test Station, 15 June 1957.

NOTS 1938 (brochure). *NOTS Supersonic Tracks.* China Lake: U.S. Naval Ordnance Test Station, 1 July 1958.

NOTS 2000, Rev. 1. *Status Report on the Naval Observational Television Satellite Project.* China Lake: Weapons Development Dept., U.S. Naval Ordnance Test Station, 2 April 1958.

NOTS 2056. *An Exploratory Program Leading to Military Meteorological Observations From Television Satellites*, by Robert G. S. Sewell. China Lake: Weapons Development Dept., U.S. Naval Ordnance Test Station, 27 June 1958.

NOTS 2068. *Weapons Journal of Research, Development, and Test*, Vol. 1, No. 1. China Lake: U.S. Naval Ordnance Test Station, 1 January 1959.

NOTS TM 379. *Exterior Ballistics of the 6."5 Anti-Tank Aircraft Rocket (ATAR), Pt. 1. Experimental*, by Leroy Riggs. China Lake: Research Dept., U.S. Naval Ordnance Test Station, 1 October 1950.

NOTS TM 452-5. *A Heat Homing Rocket*, by William B. McLean. China Lake: Aviation Ordnance and Test Dept., U.S. Naval Ordnance Test Station, 20 June 1949.

NOTS TM 1653 (NVD 1269). *Status Report of Sidewinder Program as of 1 August 1953*, by Dr. H. A. Wilcox and Lieutenant T. J. Christman. China Lake: Aviation Ordnance Dept., U.S. Naval Ordnance Test Station, August 1953.

NOTS TM 1678. *U.S. Navy Air-to-Air Guided Missile AAM-N-7 Sidewinder Service Information*, by Howard A. Wilcox. China Lake: Aviation Ordnance Dept., U.S. Naval Ordnance Test Station, 2 March 1954.

NOTS TM 1782. *Early Guided-Missile Testing at NOTS (1945–1951)*, compiled by A. B. Christman. China Lake: Test Dept., U.S. Naval Ordnance Test Station, 30 July 1954.

NOTS TP 2244, Rev. 1. *ZUNI 5.0-Inch High-Performance Folding-Fin Aircraft Rocket: A Handbook for the Ordnanceman*. China Lake: U.S. Naval Ordnance Test Station, 29 September 1959.

NWC TP 6413, Part 1. *Major Accomplishments of the Naval Weapons Center and Its Predecessor Organizations*. China Lake: Technical Information Dept., Naval Weapons Center, December 1982.

NOTS TS 64-241, "NOTS: Weapons Forge for National Defense," U.S. Naval Ordnance Test Station, September 1964.

OPNAV Report 5750-5. *History of the U.S. Naval Ordnance Test Station China Lake, California, August 1945—December 1958*, Chapter VII. China Lake: Management Research Div., Central Staff, U.S. Naval Ordnance Test Station, circa 1958.

Pacific Missile Test Center. *Days of Challenge Years of Change: A Technical History of the Pacific Missile Test Center*. Point Mugu: Pacific Missile Test Center, 22 August 1989.

Pierson, Erma. *Kern's Desert*. Bakersfield: Kern County Historical Society and County of Kern, Publication 18, 1956.

Rabinow, Jacob. *Inventing for Fun and Profit*. San Francisco: San Francisco Press, Inc., 1990.

Rearden, Steven L. *History of the Office of the Secretary of Defense, Volume I. The Formative Years, 1947–1950*. Washington: Historical Office, Office of the Secretary of Defense, 1984.

Robbins, J. M., and R. W. Feist. *The China Lake Propulsion Laboratories*. Ridgecrest: Naval Air Warfare Center Weapons Div. and Comarco, Inc., July 1992.

Rockefeller Brothers Fund, Inc. *International Security. The Military Aspect*. Garden City: Doubleday Headline Publications, Special Studies Report II, 1958.

Sapolsky, Harvey M. *The Polaris System Development. Bureaucratic and Programmatic Success in Government*. Cambridge: Harvard University Press, 1972.

_____. *Science and the Navy: The History of the Office of Naval Research*. Princeton: Princeton University Press, 1990.

Schirra, Captain Walter M., Jr., with Richard N. Billings. *Schirra's Space*. Boston: Quinlan Press, 1988.

Smith, Bernard. *Looking Ahead From Way Back: An Autobiography.* Richmond, IN: Prinit Press, 1999.

Smith, Merritt Roe, ed. *Military Enterprise and Technological Change: Perspectives on the American Experience.* Cambridge, London: MIT Press, 1985.

Swenson, Lloyd S., Jr., James M. Grimwood, and Charles C. Alexander. *This New Ocean: A History of Project Mercury.* Washington: Scientific and Technical Information Div., Office of Technology Utilization, National Aeronautics and Space Administration, NASA SP-4201, 1966.

Trumbull, Jonathan. *Multicrises: Sea Power and Global Politics in the Missile Age.* Cambridge, London: MIT Press, 1971.

Turner, Gordon B., and Richard D. Challener, eds. *National Security in the Nuclear Age: Basic Facts and Theories.* New York: Frederick A. Praeger, 1960.

Ulanoff, Stanley M., ed. *Fighter Pilot.* Garden City: Doubleday & Co., Inc., 1962.

U.S. Congress. *Inquiry Into Satellite and Missile Programs.* Hearings Before the Preparedness Investigating Subcommittee of the Committee on Armed Services, U.S. Senate, 84th Congress, 1st and 2nd Sessions, Part 1. 25, 26, 27 November and 13, 14, 16, and 17 December 1957; 10, 13, 15, 16, 17, 20, 21, and 23 January 1958; Part 2. 6, 8, 9, 10, 13, 14, 15, 16, 17, 20, 21, and 22 January 1958. Washington: Government Printing Office, 1958.

U.S. Congress. *Study of Airpower.* Hearings before the Subcommittee on the Air Force of the Committee on Armed Services, U.S. Senate, 84th Congress, 2nd Session, 16 April–19 July 1956. Washington: Government Printing Office, 1956.

U.S. House of Representatives, U.S. *Organization and Administration of the Military Research and Development Programs.* House Report No. 2618, Union Calendar No. 895, 24th Intermediate Report of the Committee on Government Operations, 83rd Congress, 2nd Session. Washington: Government Printing Office, 4 August 1954.

Weir, Gary E. *Forged in War: The Naval-Industrial Complex and American Submarine Construction, 1940–1961.* Washington: Naval Historical Center, 1993.

Westrum, Ron. *Sidewinder: Creative Missile Development at China Lake.* Annapolis: Naval Institute Press, 1999.

White, Maxwell. *An Interpretive History of the Pacific Missile Test Center. The Genesis: Road to Point Mugu 1936 to 1946.* Point Mugu: Pacific Missile Test Center, 1 July 1991.

Winton, John. *Air Power at Sea: 1945 to Today.* New York: Carroll & Graf Publishers, Inc., 1987.

York, Herbert. *Race to Oblivion: A Participant's View of the Arms Race.* New York: Simon and Schuster, 1970.

Younkin, Elva, ed. *Coso Rock Art: A New Perspective.* Publication 12. Ridgecrest: Maturango Press,1998.

Articles and Papers

Allard, Dean C. "Interservice Differences in the United States, 1945–1950: A Naval Perspective." *Airpower Journal* (Winter 1989): 73–84.

Allison, David K. "U.S. Navy Research and Development since World War II." *Military Enterprise and Technological Change: Perspectives on the American Experience,* Merritt Roe Smith, editor. Cambridge, London: MIT Press, 1985, 289–328.

Anon. "GMU-61 Has Key Missile Role." *Naval Aviation News* (October 1957): 14.

_____. "Government Research in Peril?" *Chemical and Engineering News* 32 (9 August 1954): 3134–3137.

______. "Harnessing the Navy's Mighty Mouse!" *Skyline* North American Aviation (May 1951): 19–21.

______. "The War on the Testing Ground." *LIFE* (18 September 1950): 76–78.

Baldwin, Hanson W. "New Rocket 'Fleet' Tested on Desert." *New York Times*, 2 May 1950, 21.

Barlow, Dr. Jeffrey G. "The Navy and the Bomb: Naval Aviation's Influence on Strategic Thinking, 1945–1950." In *A Time of Change: National Strategy in the Early Postwar Era.* Colloquium on Contemporary History, Naval Historical Center, Washington 1 (7 June 1989): 13–28.

______. "'The Revolt of the Admirals' Reconsidered," Eighth U.S. Naval History Symposium, U.S. Naval Academy (September 1987): 224–243.

Christman, Al. "Deak Parsons Officer-Scientist." *U.S. Naval Institute Proceedings* 118 (January 1992): 56–61.

Clarke, Ronald W. "The Deadly Sidewinder." *Fly Past* (September 1988): 36–39.

Dulles, John Foster. "The Evolution of Foreign Policy." Speech to Council on Foreign Relations, 12 January 1954. *U.S. Department of State Bulletin* 30, 761 (25 January 1954): 106–110.

Fialka, John J. "Weapon of Choice: After Nearly 30 Years, Sidewinder Missile is Still Potent, Reliable." *Wall Street Journal*, 15 February 1985, 1, 34.

Gardner, Trevor. "Must Our Air Force Be Second Best?" *Look* (1 May 1956): 77–83

Golden, William T., ed. "President's Science Advisory Committee Revisited." *Science, Technology & Human Values* 11, 2, 55 (Spring 1986): 5–28.

Hall, R. Cargill. "Earth Satellites, a First Look by the United States Navy in the 1940's," presented at the Fourth History Symposium, International Academy of Astronautics, Constance, Germany. Jet Propulsion Laboratory (9 October 1970): 1–44.

Halperin, Morton H. "The Gaither Committee and the Policy Process." *World Politics* (April 1961): 360–384.

Hamilton, Gordon C. "The Mighty Mouse: It Guards America in the Air." *Newsweek* (23 March 1953): 33–35.

Holmquist, Captain C. O., USN, and R. S. Greenbaum. "Navy's 'In-House' Research Laboratories." *U.S. Naval Institute Proceedings* 88 (February 1962): 68–75.

Hooper, Captain Edwin B., USN. "Reorganizing and Maintaining Momentum." *Armed Forces Management* (August 1959) 36–38.

______. "The Navy Department: Evolution and Fragmentation," Naval Historical Foundation II, No. 22, Spring 1978, 36-page pamphlet.

Hughes, Lt. Warren R., USNR. "By the Rocket's Red Glare: Inyokern," *U.S. Naval Institute Proceedings* 75 (November 1949): 1207–1215.

Kershner, R. B. "The Size of Research and Engineering Teams," In *The Proceedings of the Eleventh National Conference on Administration of Research, September 4, 5, 6, 1957, the Johns Hopkins University, Applied Physics Laboratory.* Pennsylvania State University Press, University Park, PA (September 1957): 77–83.

Klass, Philip J. "Competition Slashes Sidewinder 1-A Price." *Aviation Week and Space Technology* (9 April 1962): 89–95.

Lubell, Samuel. "Sputnik and American Public Opinion." *Columbia University Forum* (Winter 1957): 15–21.

Marvin, J. R., and F. J. Weyl. "The Summer Study." *Naval Research Reviews* (August 1966): 1–7, 24–28.

Miles, Marvin. "Navy's Sidewinder Missile Downs Fighter in First Demonstration." *Los Angeles Times* (4 March 1957): 1, 21.

_____. "Times Man Flies Missile Mission." *Los Angeles Times*, 6 May 1957, Part 1, 2–3.

Newkirk, H. L., W. R. Haseltine, and A. V. Pratt. "Stability of Rotating Space Vehicles." *Proceedings of the IRE* (April 1960): 743–750.

Newkirk, Horace L. "Aeroballistics Testing Facilities at the U.S. Naval Ordnance Test Station, Inyokern." Meeting of the Bumblebee Aerodynamics Panel, Applied Physics Laboratory, Johns Hopkins University, Silver Spring, MD (8 April 1953): 3–4.

Olson, Richard D. "White Mountain Research Station: Institution of 'Highest' Learning." *Naval Research Reviews* (July 1966): 5–11.

Paolucci, Captain Dominic A., USN (Ret). "The Development of Navy Strategic Offensive and Defensive Systems." *U.S. Naval Institute Proceedings* 96 (May 1970): 204–223.

Price, E. W. "Combustion Instability." Michelson Laboratories, NOTS TP 2400, Technical Article 3 (March 1960): 1–12.

Price, E. W., C. L. Horine, and C. W. Snyder. "Eaton Canyon: A History of Rocket Motor Research and Development in the Caltech-NDRC-Navy Rocket Program, 1941–1946," 34th AIAA/ASME/SAE/ASEE Joint Propulsion Conference & Exhibit, 13–15 July 1998, Cleveland, Ohio. AIAA 98-3977.

Ray, Thomas W. "The Bureaus Go On Forever." *U.S. Naval Institute Proceedings* 94 (January 1968): 50–63.

Riley, John. "The Navy's Top Handyman." *LIFE* (6 January 1967): 31–35.

Stone, Irving. "Navy Shows Sidewinder's Lethal Power." *Aviation Week and Space Technology* 66 (11 March 1957): 26–27.

_____. "Paper Makes Expendable Rocket Launcher." *Aviation Week and Space Technology* 63 (11 October 1954): 40–42.

Stroop, Rear Admiral Paul D. "Naval Weapons Development." *Ordnance* (March–April 1960): 727–730.

Talkington, Howard R. "NOTS, San Clemente Island." *U.S. Naval Institute Proceedings* 86 (June 1960): 92–101.

Thompson, Dr. L.T.E. "Naval Ordnance Research: Developing New Weapons for Air and Underwater Combat." *Ordnance* (November–December 1950): 4.

Tikalsky, J. D. "Radar Raiders." *Naval Aviation News* (November 1953): 1–5.

Tillman, Barrett. "In Harm's Way. The Saga of Gambier Bay." *The Hook: Journal of Carrier Aviation* (Winter 1986): 40–53.

Troll, John H. "Of Sidewinders and Dead Ends." *The Reporter* (13 November 1958): 21–23.

Vieweg, Captain Walter V. R., USN. "Testing Naval Ordnance. Task of the Research and Development Center at Inyokern." *Ordnance* (July–August 1952): 70–72.

Wiesner, Jerome B. "On Science Advice to the President." *Scientific American* 260 (January 1989): 34–39.

York, Herbert F., and G. Allen Greb. "Military Research and Development: a Postwar History." *Bulletin of the Atomic Scientists* (January 1977): 13–25.

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