POSTWAR CONTINUITY

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Introduction

National leaders praised wartime research and development efforts and agreed that peacetime R&D was vital to the nation. After the war, organization of research changed. The Navy bureaus took over management as well as sponsorship of the laboratories. In San Diego, NRSL and UCDWR became the Navy Electronics Laboratory (NEL). In Pasadena, the facilities previously operated as part of Caltech's wartime rocket and torpedo development work were transferred to become the NOTS Pasadena Annex.

NEL continued NRSL's work in ship antenna development and directivity. Efforts were directed toward minimizing the number of antennas and using ship structural elements to enhance antenna performance. NEL continued UCDWR work on radar beacons; the precision RACON system went to the Fleet in 1949. Work continued on aircraft recognition systems, which included development of the Mk X Identification Friend or Foe (IFF) prototype. NEL also completed the Sound Fixing and Ranging (SOFAR) system for locating survivors at sea. And NEL's long interest in the interaction of submarines with the submerged environment led to pioneering studies of the Arctic.

NOTS Pasadena Annex continued work on air-dropped torpedoes, a task made more challenging with the advent of jet airplanes. Engineers built innovative new facilities to test new designs. Work also continued on standoff ASW weapons and led to the development of the rocket-propelled Weapon A.

Peacetime Defense Research

Although the U.S. military scaled down severely after the war, the government had learned the value of scientific research and development and wanted to maintain a permanent, peacetime research capability that could expand rapidly if needed and keep abreast of technological change. Vannevar Bush spoke for many, inside and outside of military science, in his final report as head of OSRD:

> *In this war it has become clear beyond all doubt that scientific research is absolutely essential to national security. The bitter and dangerous battle against the U-boat was a battle of scientific techniques—and our margin of success was dangerously small. The new eyes which radar supplied to our fighting forces quickly evoked the development of scientific countermeasures which could often blind them. This again represents the ever continuing battle of techniques. The V-1 [unguided missile] attack on London was finally defeated by three devices developed during this war and used superbly in the field. V-2 [the first guided missile] was finally countered only by capture of the launching sites.... There must be more—and more adequate—military research during peacetime. We cannot rely on our Allies to hold off the enemy while we struggle to catch up. Further, it is clear that only the Government can undertake military research; for it must be carried on in secret, much of it has no commercial value, and it is expensive. The obligation of Government to support research on military problems is inescapable. It is essential that the civilian scientists continue in peacetime some portion of those contributions to national security which they have made so effectively during the war.*

It remained for the Navy to organize its postwar research effort.

The Bureau Structure of Navy Research

The Navy emphatically supported the need for peacetime R&D, even as it demobilized its big wartime fleet. Although OSRD had managed the new wartime laboratories at San Diego and Pasadena, their actual funding had come mainly from three of the Navy's material bureaus (Ships, Ordnance, and Aeronautics), which traditionally supplied the material needs of the Fleet. As the war ended, the Navy decided to replace OSRD by having the bureau sponsors of its R&D become the managers of its R&D, too.

In 1946, Navy organization distinguished between the command responsibilities of the Chief of Naval Operations (CNO) and the support role played by the material bureaus. CNO determined fleet needs, and the bureaus filled those needs. The seven bureaus, some dating from the 1840s, were all organized around particular functions central to the fleet's activities: medicine (BuMed), ship construction (BuShips), yards and docks (BuDocks), supplies and accounts (BuSandA), personnel (BuPers), ordnance (BuOrd), and aeronautics (BuAir). BuShips, BuOrd, and BuAir sponsored most of the research and development at the two laboratories that became NOSC.

San Diego: From NRSL/UCDWR to Navy Electronics Laboratory (NEL)

In 1945, the U.S. Navy Electronics Laboratory (NEL) was established to continue the electronics and underwater acoustics work performed by its two World War II predecessors, NRSL and UCDWR. (NRSL was renamed the U.S. Navy Electronics Laboratory on 29 November 1945, and on 30 June 1946, UCDWR's remaining projects and contracts were absorbed and continued by NEL.) Many UCDWR employees transferred to the civil service payroll of NEL. A certain portion of work also came to NEL from incomplete OSRD work being done for the Navy at Harvard and the Massachusetts Institute of Technology (MIT).

Placed under BuShips, NEL was tasked "to effectuate the solution of any problem in the field of electronics, in connection with the design, procurement, testing, installation and maintenance of electronic equipment for the U.S. Navy." Captain Paul Hord managed the transition to NEL. He was designated Commanding Officer (CO) and Director and had overall command responsibility for the laboratory, much as a CO does for a ship at sea. In Captain Hord's view, the function of the Navy Electronics Laboratory would shift from fleet support to basic research. As he put it in 1946, "To fulfill its mission, the Laboratory must remain a scientific institution wherein scientific work is performed by scientists under the direction of scientists. The future of NEL depends solely on the scientific results it produces. The stature of NEL is directly proportional to the stature of its scientific personnel."

In January 1946, the position of a civilian "Superintending Scientist" was created but remained unfilled until the autumn of 1948 when J. P. Maxfield was appointed.

Defining Postwar Research

BuShips broadly defined what was expected of NEL's postwar naval research: (1) to study and improve all the electronic equipment aboard a single ship or single class of ships; (2) to continue to develop, test, modify, and support radar and radio communication equipment developed at San Diego or at other Navy laboratories; (3) to study, at the level of fundamental research, the propagation of electromagnetic energy in the atmosphere and of sound in the ocean; (4) to continue to develop sonars and training aids for sonar operators; and (5) to assist the Fleet by training its personnel as needed. These mission areas, seemingly narrowly drawn, would require basic research in several related fields, notably physics, mathematics, meteorology, and marine biology and would also require the development of professional expertise in electrical, electronic, and mechanical engineering.

BuShips, as its name implied, designed, built, and maintained the ships of the Fleet, including their electronics. BuShips organized its work in electronics on the basis of projects, which were given to research and development teams at its laboratories. This direct tasking promoted very close ties between project managers at NEL and their "sponsors" in the Bureau—officers who administered BuShips funds allocated for the particular task.

NEL Growth

Although the Navy as a whole scaled down after the war, the San Diego Laboratory grew. In terms of physical plant, NEL originally comprised three buildings on Point Loma (the present Topside buildings 1, 2, 4, and various small buildings), two waterfront buildings, an abandoned coastal defense battery at the tip of the Point (Battery Humphrey), and field stations at two city reservoirs (Sweetwater and El Capitan) plus another at Sentinel, Arizona, adjacent to Luke Air Force Base.

In August 1947, NEL gained 11 acres from the Navy's Fuel Facility as well as all structures of the Small Craft Facility (today NOSC Bayside). In the summer of 1947, NEL also took possession of USS *Baya* (SS 318) to support underwater research. In 1949, NEL acquired 11.2 more acres of Bureau of Public Health lands and buildings (the old Quarantine Station at Ballast Point).

The growth of work at NEL was such that the 80th Congress authorized construction of a large new building. The Commandant of the 11th Naval District, Rear Admiral Wilder Baker, broke ground for the new structure on 24 June 1949. The building was designed to be built and opened in stages, so that the first wings could be used while the rest was still being built. Wings 1 and 2 were built over the next 3 years, and the structure (known as Building 33) opened in 1950.

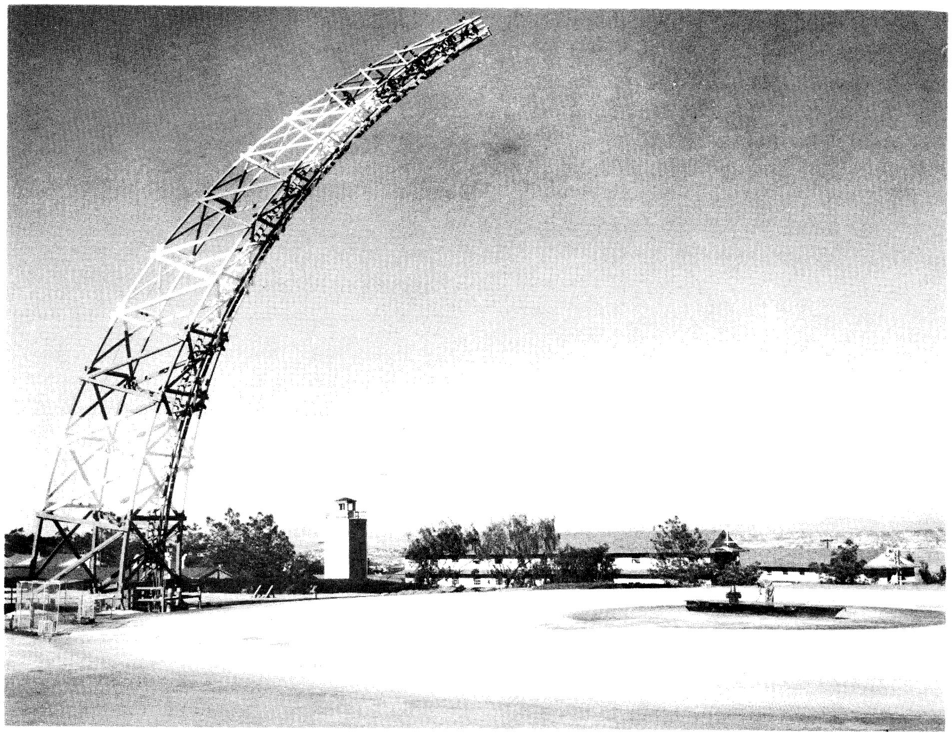
Groundbreaking ceremony for Building 33 on 24 June 1949. Wielding the shovel is RADM W. D. Baker, USN, Commandant of the Eleventh Naval District. Watching (center) is CAPT R. Bennett, USN, Director of NEL.

NEL: Continuing Research in Peacetime

Electronic Architecture

NEL continued the wartime studies of ship antenna development and directivity undertaken by NRSL. Self-interference was a problem that advances in electronics only increased. New radars in some destroyer classes required an additional mast to accommodate the forest of radar and counter-radar antennas. During the postwar years, considerable effort went into minimizing the number of antennas by multicoupling, that is, using one antenna to receive signals on different wavelengths simultaneously. A parallel effort involved using ship structural elements to enhance antenna performance.

In 1945, NEL began building the Antenna Model Range to support this work. By 1947, NEL engineers



Antenna Model Range. The model ship, 1/48th scale, is mounted on a brass-covered turntable 22 feet in diameter centered in a lead-covered circular concrete base.

began the first tests with scaled-down brass models of ships. The Model Range uses scaled-up frequencies on scaled-down ship models (1/48th scale today) to measure antenna performance and to assess the interaction (desirable and undesirable) among the radiating elements and the ship's superstructure. An important milestone of this effort was the recommissioning of USS *Mount McKinley* (AGC 7) in 1951, in which NEL engineers reduced the number of antennas to one-third the total originally required, with no loss in performance.

The UC Connection Preserved: The Marine Physical Laboratory

When UCDWR and NRSL activities were combined to form NEL, a group of San Diego scientists continued their UC affiliation and remained at Point Loma to form the Marine Physical Laboratory (MPL). MPL was established in 1946 at NEL to continue basic (i.e., pure scientific) research on underwater acoustics started by UCDWR. MPL's director was Professor Carl Eckart, past assistant director of UCDWR's Sonar Data Division. MPL, with Navy sponsorship, conducted research in oceanography and physics and remains (in 1990) an important Navy contract laboratory managed by the University of California's Scripps Institution of Oceanography.

Navigation Systems

During the war, UCDWR had developed radar beacons (racons) to assist in navigation. During the late 1940s, NEL electronics engineers developed the first of a series of navigation systems based on advances in electronics. The result, the precision RACON system, went to the Fleet in 1949. The RACON system allowed precise navigation of harbors and beachheads and was used for tactical air support during the Korean War.

Identification Friend or Foe (IFF)

UCDWR had worked on aircraft recognition systems (generally known as IFF) during the war. The principle behind IFF was that a suitably equipped aircraft or ship could electronically interrogate an unknown aircraft and determine whether it was hostile or friendly. An airplane equipped with an IFF system automatically transmits a series of pulses in the form of a code to the receiver on the ground, in the air, or onboard ship. Originally developed to avoid shooting down one's own aircraft, IFF could be and was extended to encompass submarines and surface ships.

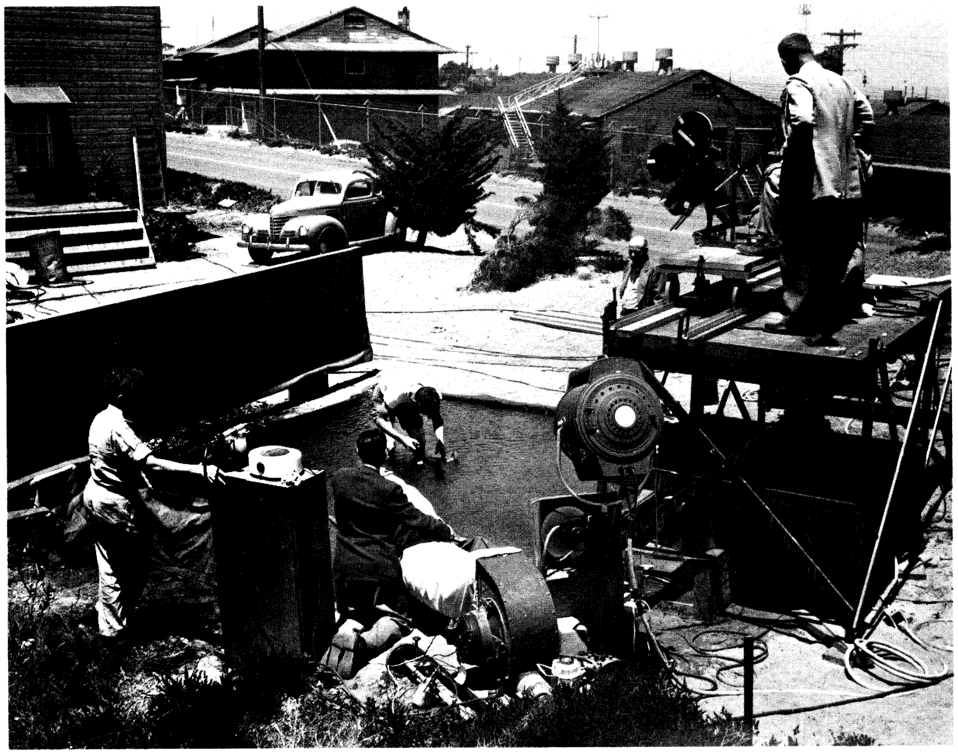
However, in 1945, IFF systems could only respond to an interrogation. They could not convey detailed information as to type, unit, or course. Beginning in 1947, NEL researchers developed the selective identification features that enabled interrogating IFF systems to receive detailed information from a transponder aboard a ship, submarine, or aircraft.

NEL prepared the initial concept as well as the prototype hardware of the Mk X IFF system. Operational evaluation, with 10 aircraft, took place in 1951, and the first system was with the Fleet the following year. During the 1950s, the Mk X IFF became operational with all U.S. and North Atlantic Treaty Organization (NATO) forces and continued in use into the 1970s on military and civilian aircraft and ships. As a result of NEL's pioneering work, selective identification features were incorporated into the IFF systems developed since for use by American and Allied military and civilian aircraft. The benefits of this work were primarily realized in civil air traffic control. Not only did selective identification features enable controllers to process significantly more information, but data from the new system proved easy to format for entry into computer systems.

The SOFAR System

During the war, UCDWR had begun work on the Sound Fixing and Ranging (SOFAR) system for locating and rescuing ship and aircraft survivors at sea. As implemented, the SOFAR system required survivors from a plane to drop a miniature depth charge into the water. The depth charge would sink and explode at the optimal depth for sound transmission, 3500 feet. Hydrophones placed at the same depth and cabled to shore stations

SOFAR system. Model study for SOFAR movie.



would receive the signal and by triangulation locate the source of the sound and hence be able to direct rescuers. After the war, NEL scientists completed the system, which consisted of a network of three radio direction-finding stations in the eastern Pacific, to provide long-range reception of low-frequency signals deep in the ocean. Later, the SOFAR system was used for basic research in underwater sound.

Pioneering Arctic Research

The Navy's submarine arctic work was an outgrowth of NRSL's antisubmarine warfare (ASW) and harbor defense work of World War II. The Canadian Navy had asked that Puget Sound be evaluated since its harbor defense system was the most complete and elaborate of all World War II systems. The evaluation was expanded to study why German U-boats had been so successful in sinking ships in the Gulf of Saint Lawrence and evading Canadian ASW efforts. Ocean conditions were thought to be similar in Puget Sound and the Gulf of Saint Lawrence. Since the U-boats had used the winter ice cover in the Gulf to evade ASW ships, the question of submarines under ice also became a part of the joint U.S./ Canadian study.

This study led to Dr. Waldo Lyon's early experiments with diesel-electric submarines. Up to this point, the ice canopy appeared to present an insurmountable barrier both to surface ships and air-breathing diesel-electric submarines. Everyone knew the physical hazards of collisions with ice, and submarines were more frail and had far less buoyancy than surface ships. So how could they navigate beneath the ice and hope to survive? At that time, almost no knowledge of the underside of the ice canopy existed. Many thought it was perfectly smooth, so that a ski-equipped submarine could transit the Arctic by gliding along the underside of the arctic ice pack.

The skills necessary to handle submarines in the open ocean differed greatly from the skills that would be necessary to dive, surface, and clear obstacles under the ice. The variations in salinity due to ice melting would affect buoyancy and other aspects of handling submarines. Oceanographers knew that the Bering and Chukchi Seas were quite shallow (140 feet in places) and feared that the rest of the Arctic Ocean would be equally hazardous. Plus, submarines had no way of knowing reliably how close they were to either the ocean bottom or the ice cap, so no matter how skillful a submariner, the chances of collision, damage, and sinking were real. Finally, diesel-electric submarines had to recharge their batteries by periodically running their diesel engines, either while surfaced or while "snorkeling" (proceeding just below the surface with an air pipe extended like a periscope to ventilate exhaust and take in air for the crew and the diesel engines). The Navy's *Naval Arctic Operations Handbook*, published in 1949, was dismissive: "The development of the transarctic submarine remains in the realm of fantasy."

Dr. Lyon and a small group of physicists at NEL disagreed. Dr. Lyon hypothesized that practical navigation beneath the ice required a scanning device, that is, active sonar, similar to the QLA developed at UCDWR. In the summer of 1947, Lyon was aboard USS *Boarfish* (SS 327) when it penetrated 6 miles under the polar ice cap. The scanning sonar worked fine, and the crew had no difficulties using it. In a pioneering, but little noticed, technical report of 1948 (NEL TR 88), Lyon argued that, "The reality of a polar submarine that can navigate the entire Arctic Ocean is not only admissible, but may be an immediate practicality." As Lyon put it, "The prerequisite equipments for under-ice navigation are standard, available equipments, though the techniques of interpretation are new." Dr. Lyon and like-minded NEL scientists soon demonstrated just how immediately arctic navigation could begin. They set to work in the late 1940s on converting a fathometer for under-ice navigation by inverting it on the topside of a submarine so that it could provide accurate information on the ice-fields through which the submarine was sailing. By devising a method of printing echoes from the fathometer on a strip of paper, Dr. Lyon's work enabled a submariner to follow his boat's progress underneath the ice.

Battery Whistler after conversion for use by NEL. The old mortar battery was converted to a laboratory for testing the effects of seawater and different water pressures on materials devices used by submarines.

The first inverted fathometer was mounted on the upper deck of USS *Carp* (SS 338) in September 1948 and tested in the Arctic Ocean later in the year. Thus equipped, *Carp* made vertical dives and ascents through open-water lakes in the ice pack. These accomplishments proved Dr. Lyon's point—that properly equipped and handled submarines could safely navigate even in the shallows of the Bering and Chukchi Seas.

Tested over a series of arctic cruises, the inverted fathometer revealed what many had suspected—the arctic ice pack was diverse in character, varied in thickness, and had enough leads (narrow channels of water) and polynyas (areas of open water) to allow submarines to surface. But there were also dangerous "ice keels," deep ridges that hung down from the main canopy, which a submarine had to avoid.

Once the basic equipment and techniques had been developed, experiments to develop information about sound propagation in the Arctic were necessary to learn exactly how the equipment functioned. NEL's work in developing the technology for piloting submarines under the ice was a combination of developing the sonar equipment, charting the sea floors, and learning about the ocean under the ice and sea-ice physics. In addition, NEL scientists, like their World War II precursors, accompanied the submarines to instruct submariners in using NEL-developed equipment, to evaluate performance, and to pinpoint problems that showed up in the field. To support these summer expeditions year-round, NEL began in the late 1940s to convert an unused U.S. Army coastal defense mortar battery, Battery Whistler, into the Deep Submergence Laboratory. This laboratory would be used for testing the effects of seawater and different water pressures on materials and devices intended for use by submarines. Known subsequently as the Submarine Research Facility, it became the Arctic Submarine Laboratory in 1969.

Pasadena: From Caltech to NOTS Pasadena Annex

Caltech had already decided in April 1945 not to continue direct involvement with Navy weaponry. As a result, BuOrd in October 1945 took over direct control of rocket and torpedo development, and about 80 percent of Caltech contract employees working in those groups accepted civil service employment with the Navy.

General Tire and Rubber (GTR) operated the main Pasadena building, the Foothill Plant, as a Navy contractor. Under the contract, BuOrd dealt directly with GTR, whose employees administered the test station at Inyokern as well as the scientific activity in Pasadena and at Morris Dam. In July 1948, approximately 400 employees of GTR accepted civil service positions with NOTS in Pasadena, bringing the total number of employees there to 700. For several years, Pasadena housed the administration of NOTS: personnel, payroll, and facilities, in addition to the underwater ordnance department, and was generally referred to as the "Pasadena Annex" or later as "NOTS Pasadena," which is the name we will use here.

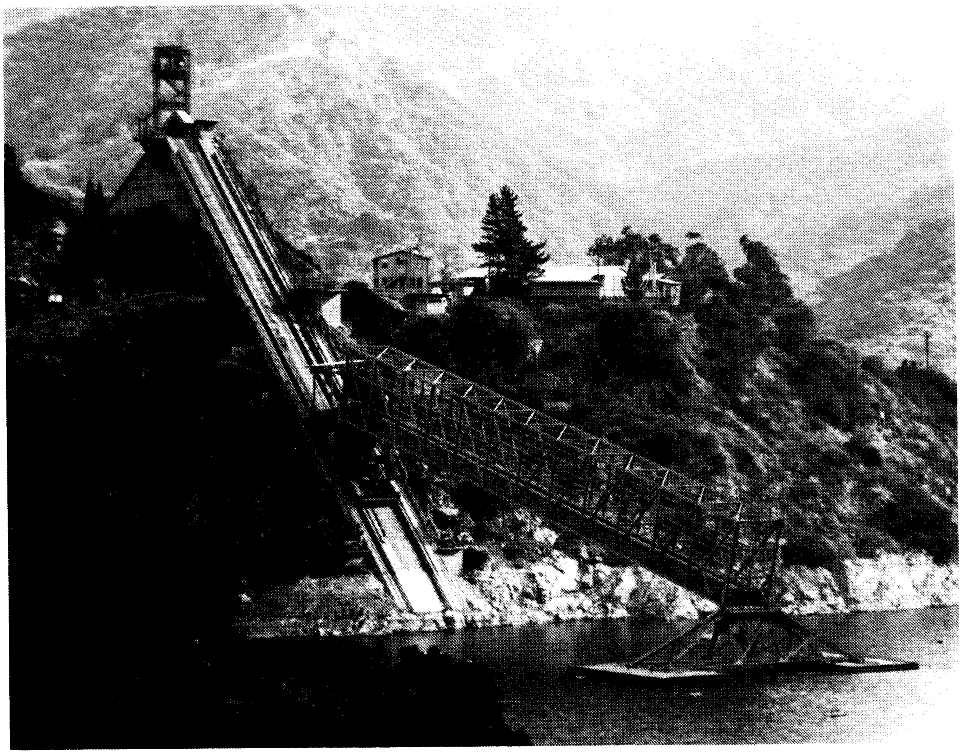
NOTS Pasadena: Lightweight Torpedoes in the Jet Age

Air-Dropped Torpedoes

The advent of jets gave a new impetus to research on air-dropped torpedoes, since the increased speed of the new aircraft in turn increased the stresses of the torpedoes' water entry. Also, with improved antiaircraft armament and superior, radar-directed fire control developed during the war, aircraft had to drop their torpedoes farther away from their targets. Thus, air-dropped torpedoes would have to be faster and have greater range than those already in use. In July 1946, BuOrd formally tasked NOTS Pasadena to develop a 1000-pound, high-speed torpedo that could be dropped from an aircraft traveling at 600 knots (~700 mph) and at an altitude of 10,000 feet. To put this in perspective, remember that only 5 years earlier, the British "Swordfish" aircraft that torpedoed the *Bismarck* were biplanes flying at 100 mph and dropping their ordnance at 50 feet above the sea.

Whether a faster torpedo with greater range could be built was not yet clear in 1946, but it was plain to NOTS that the existing test facilities at Morris Dam would not be adequate. As early as 1943, engineers at Morris Dam had started work on improving the Mk 13 torpedo, the first torpedo designed specifically for aircraft launching. Initial results indicated that only a torpedo of a radically new design would permit a higher water-entry speed caused by faster jet aircraft.

VAL at Morris Dam. An enhanced version of the fixed-angle launcher, the VAL allowed scientists to vary the angle of water entry of torpedoes to approximate different air-drop speeds and altitudes.



The Variable-Angle Launcher (VAL)

Plans for an enhanced version of the fixed-angle launcher at Morris Dam had been drawn up before the war ended, but construction of the new variable-angle launcher (VAL) did not begin until 1947. General Tire and Rubber, through a construction contract, completed the VAL by the summer of 1948. As designed, the VAL was a 300-foot steel bridge with a launching tube 22.5 inches in diameter. By pivoting one end of the bridge on a crosspiece that connected two floating barges, the angle of water entry could be shifted to approximate different air-drop speeds and altitudes. Compressed air shot a torpedo out of the 300-foot launching tube, and a battery of high-speed cameras filmed the projectile as it hit the water. Instrumented testheads aboard the torpedoes measured the stresses of the impact. All the resulting data were available for subsequent analysis.

Important ancillary facilities at Morris Dam built during this time included a rocket launcher for studies of trajectory and velocity of projectiles underwater and a barge-mounted rail launcher to model over-the-side torpedo launches or to study the impact of exploders against armor plating. Similarly, General Tire and Rubber built small barge-mounted VALs for smaller ordnance and for higher initial velocities than possible with the main unit. The propulsion laboratory at Morris Dam was expanded for experiments with chemical fuels, high-energy batteries, and various thrust-producing mechanisms.

Hydrodynamic Simulator

Prior to the late 1940s, the only means to test torpedoes was by actually running them at sea. This practice was not only expensive and infrequent, but often if a run failed, the reasons for the failure could not be determined. In 1944, Pasadena engineers began to develop test equipment to simulate the underwater environment of a torpedo. The result, the Hydrodynamic Simulator, was finished in June 1948. The Hydrodynamic Simulator was a large tank in which an actual torpedo (or other missile) could be subjected to the same forces and motions it would experience in live conditions. The idea for the simulator was based on using a 5-inch gun mount. The gun was replaced with a separate carriage, and the simulator was designed so that a Mk 13 torpedo could be placed in the carriage so as to have three degrees of freedom; it could roll about the longitudinal axis, pitch nose up and down, and change course heading. The efficiency of the torpedo's control system could be assessed and qualitative performance criteria established quickly and with much less proof-firing of new torpedoes. Thus, by the late 1940s, the Navy had a unique facility and unmatched technical expertise on which to call.

Over the years, the Hydrodynamic Simulator has gone through many upgrades to extend and expand its capabilities in lock-step with the development of successive generations of U.S. torpedoes. Capabilities such as target acoustics simulation and environmental modeling were added, and simulator target models were upgraded to reflect new intelligence data. The simulator has made major contributions to both the submarine- and air-launched torpedo programs and is doing so to this day. Now called the Hybrid Simulator, it is one of the only on-line facilities in the free world that can do realtime hardware-in-the-loop simulation to support the development, test, and evaluation of all U.S. torpedoes as well as the torpedoes of many Allied nations.

Weapon A

The increased range of submarine-launched torpedoes and the increased detection ranges offered by sonars developed during the war produced a need for standoff ASW weapons that could be launched farther ahead than previously fired by destroyers or other ASW craft. During the war, the Hedgehog and the Mousetrap had provided good service, but the function of a research and development laboratory is to anticipate, not merely react to, developments in other technologies. So, in 1946, NOTS Pasadena began work to develop a rocket-propelled standoff ASW weapon.

Working with the Naval Ordnance Laboratory in White Oak, Maryland, NOTS Pasadena developed Weapon A within 3.5 years. Fired from a deck loader, Weapon A carried a 250-pound warhead. Its solid-fuel-propelled rocket could carry it 2400 feet from the ship firing it. Weapon A entered the Fleet in 1951 and remained in inventory until 1969.

Sidewinder

During the postwar years, NOTS Inyokern became home to Dr. William McLean, a man who would later play an important role as Technical Director of laboratories at China Lake and San Diego. Once a student of Dr. Lauritsen's at Caltech, Dr. McLean transferred to Inyokern in 1945.

From 1945 to 1948, Dr. McLean developed the fundamental concept that was to transform guided missile technology: Free the missile from total dependence on both guidance control and the releasing aircraft by placing the control unit within the missile itself and designing it to seek out the radiation emitted from the target. As the target maneuvered, the missile would "lock on" to follow the radiation to its source.

Dr. McLean's design philosophy was unique for the times: If a part didn't work, find a way not to use that part at all. By solving each problem as it arose and by adding his own brand of engineering ingenuity, Dr. McLean designed the new air-to-air missile for tail attacks and named it for the sidewinder rattlesnake—an ancient resident of the Mojave Desert. The first Sidewinder missiles were released to the Fleet in 1956 and became unsurpassed in accuracy and reliability. Sidewinders are still being used by the U.S. Navy, U.S. Air Force, NATO countries, and other Allies. For his efforts on Sidewinder, Dr. McLean received the President's Award for Distinguished Federal Civilian Service, presented by President Eisenhower in 1958.