
Arming The Fleet
Supporting Naval Aviation
and Warfighter Requirements Since 1943
NAVAIR
WEAPONS DIVISION
CHINA LAKE • POINT MUGU
CALIFORNIA

Naval Aviation Vision
NAVAIR Support for *Sea Power 21*

The entire Naval Air Systems Command (NAVAIR) has made significant contributions to the Fleet, as many annual reports, command histories, and other publications have described. This one edition, entitled *Arming The Fleet*, specifically focuses on the weapons and systems research, development, test, and evaluation (RDT&E) conducted at NAVAIR's Weapons Division (WD) at China Lake and Point Mugu, California. WD has supported naval aviation and warfighter requirements since 1943–from Guadalcanal to Baghdad. This document describes WD's role in the Chief of Naval Operations' Sea Power 21, the Division's ever-increasing role in joint and international service, and quick Fleet response achievements and efficiencies in conflict. Supporting Vice Admiral Walter Massenburg's vision, *Arming The Fleet* describes how WD provides cost-wise readiness and dominant combat power to make a great Navy/Marine Corps team even better.

"To balance current and future readiness. To provide the right products to fight the global war on terrorism, and potential future conflicts." WD's contributions to more than 50 major weapon systems are described (Pages 18-51). In addition, significant data on WD support for Operation Enduring Freedom and Operation Iraqi Freedom (through September 2003) are included (Pages 69-104).

"To reduce the cost of doing business. To continue to introduce best business practices." WD has consistently applied best business practices to reduce costs (see index: *Cost Savings/Best Business Practices* Page 152).

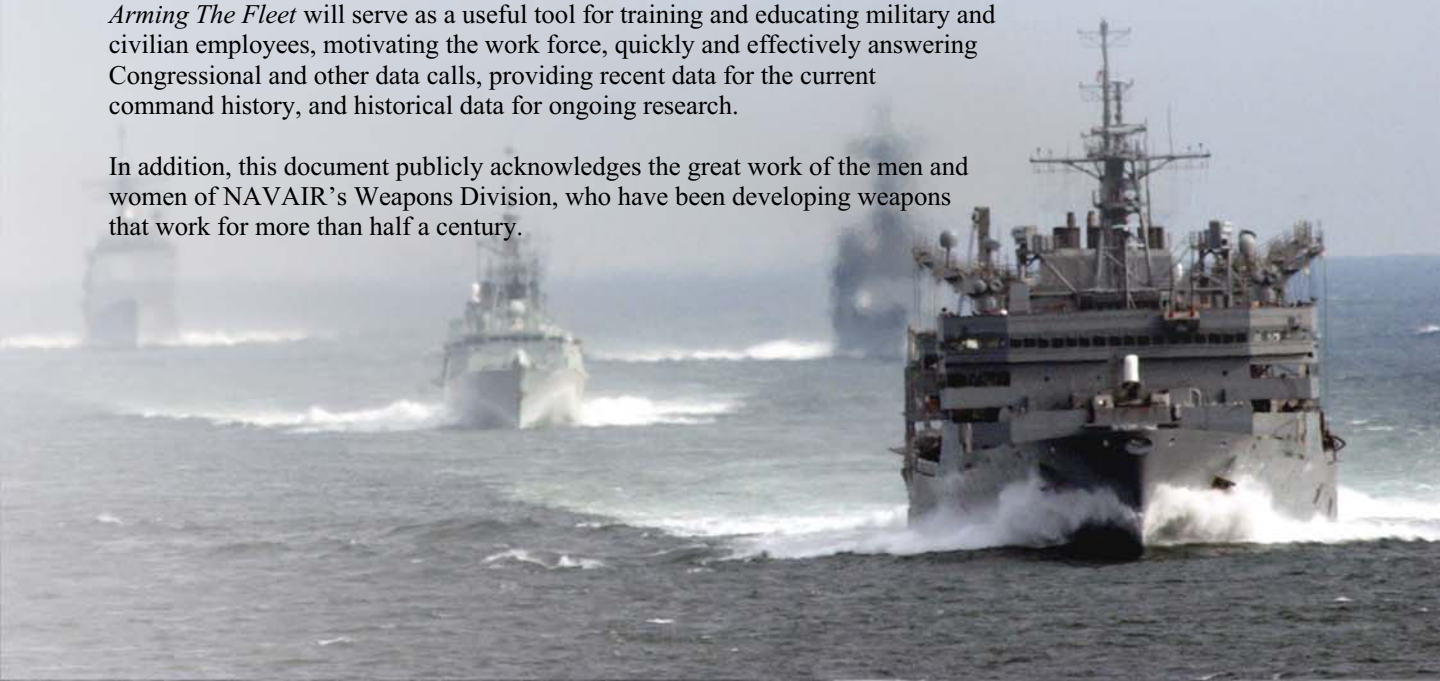
"To improve agility. To make rapid decisions supporting emerging Fleet requirements." WD quick Fleet response achievements in every major conflict since WWII are described (see *Quick Fleet Response Achievements* pages 14-15. Also, see *Rapid Prototyping For The Fleet* Page 67 and index: *Quick-Response Achievements* Page 156).

"To ensure alignment–internally and externally with CNO's transformation initiatives." WD's role in the CNO's Sea Power 21, and the Division's ever-increasing role in joint and international service is described (Pages 54-55). In addition, a complete list of Joint Activities/Partnerships with the Marine Corps, Air Force, Army, Coast Guard, other DOD agencies, international partners, industry partners, and educational institutions is included (see *Joint Activities/Partnerships* Page 160).

"To implement Fleet-driven metrics." This entire document serves as a Fleet metric as it describes how WD has supported naval aviation and warfighter requirements since 1943. (For a few highlighted examples, see index: *Requirements, Warfighter* Page 157).

Arming The Fleet will serve as a useful tool for training and educating military and civilian employees, motivating the work force, quickly and effectively answering Congressional and other data calls, providing recent data for the current command history, and historical data for ongoing research.

In addition, this document publicly acknowledges the great work of the men and women of NAVAIR's Weapons Division, who have been developing weapons that work for more than half a century.



CONTENTS

OVERVIEW

The Naval Air Systems Command (NAVAIR) delivers weapon systems to warriors for Navy and Marine Corps missions. Products and services include fixed and rotary wing aircraft, avionics, air- and surface-launched weapons, electronic warfare systems, cruise missiles, unmanned aerial vehicles, launch and arresting gear, and training systems.

NAVAIR encompasses eight sites across the country. The Aircraft Division has sites at Patuxent River, Maryland; Lakehurst, New Jersey; and Orlando, Florida. NAVAIR depots are located at North Island, California; Jacksonville, Florida; and Cherry Point, North Carolina. The Weapons Division includes sites at China Lake and Point Mugu, California. The entire NAVAIR organization has made significant contributions to the Fleet by providing total life cycle support: research, design, development, and engineering; acquisition; test and evaluation; repair and modification; and in-service engineering and logistics support. Many NAVAIR publications have documented significant contributions to the Fleet in support of naval aviation and warfighter requirements.

This document, produced by the NAVAIR Weapons Division, focuses specifically on the weapons and systems Research, Development, Test and Evaluation (RDT&E) contributions made at China Lake and Point Mugu since 1943.

During every United States military crises since World War II, RDT&E work at China Lake and Point Mugu has played a significant role: developing and testing weapons and systems that work.

Recognized Expertise. Through the years, WD has earned a national and international reputation for technical expertise in numerous areas.

Firsts. The Weapons Division provides direct Fleet support for naval aviation and is recognized for a number of significant "firsts" in weapon technology development. In addition, WD has extensive experience in developing, perfecting, and testing military components and subsystems that also have direct application to space missions. Although work for other government agencies represents only a very small fraction of the total workload, the Division is occasionally called upon by NASA to lend expertise to projects of national importance. Lessons learned from joint projects help WD find solutions to naval aviation problems. China Lake and Point Mugu are recognized for several space related and earlier undersea "firsts."

Guided Missile Development. China Lake has made significant contributions to every aspect of guided missile technology and development. WD expertise has had a significant impact in the arsenal of U.S. air-, surface-, and subsurface-launched weapons that cover virtually every threat, from enemy aircraft, to surface and sub-surface combatants, to radar systems, to hardened ground targets.

A Unique Place for Unencroached RDT&E of Weapons and Weapons Related Technology. WD is home to the largest and most diverse test range in the world, with a wide variety of features—mountains, ocean, deep-water ports, protected islands, deserts, canyons, and forests—in close proximity and all highly instrumented. The Land Ranges are larger than the state of Rhode Island, and the Sea Range is the Navy's largest test and evaluation (T&E) facility. The Division has outstanding weather for testing and conducts more than 3,000 test events each year. WD is a billion dollar per year operation with more than 6,000 employees and 40 major facilities, many of which are not duplicated anywhere else in the world.

Since the 1940s, China Lake and Point Mugu have earned a strong reputation as pioneers in experimentation. Through the years WD has contributed to more than 50 major weapon systems, including the Sidewinder missile, Joint Standoff Weapon (JSOW), and Joint Direct Attack Munition (JDAM), and the Division is now working on weapons of the future.

WD Location. China Lake is located about 150 miles northeast of Los Angeles on the western edge of California's Mojave Desert. Point Mugu is located on the Pacific Coast about 65 miles northwest of downtown Los Angeles, near the cities of Camarillo and Oxnard.

Ranked Highest in Military Value.

During 1995, the top three naval technical activities were all NAVAIR sites. Secretary of the Navy John Dalton, on June 14, stated: "…China Lake and Point Mugu [rate] number 1 and 2 in military value among all Navy activities…"

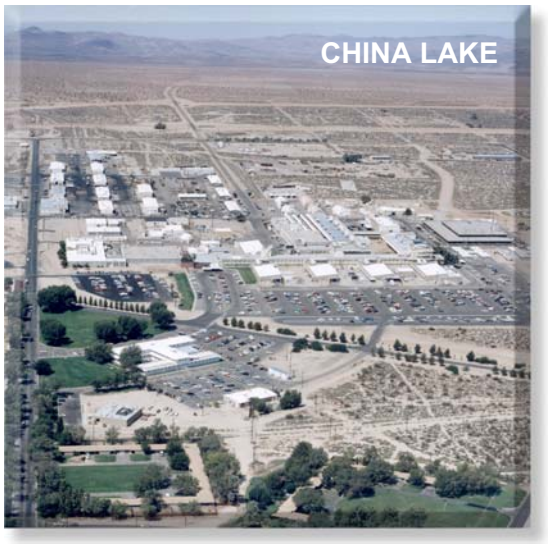
Military value includes physical and community assets and environmental and human resource factors. WD has advanced physical facilities, strong community support, low encroachment, excellent human resources, and broad mission capabilities. For example, 70 Technical Centers across the Navy were asked to carefully document their level of work involvement in 34 specific common support functions. Final results showed that no Center was involved in more than eight functions—except China Lake, which had significant documented work in 23 different functions. Point Mugu was involved in eight.[1]

Evolution of Modern Weapons. In WWII, China Lake and Point Mugu contributed extensively to several product lines that are still in use and being upgraded today, including aircraft rockets, antisubmarine weapons, guided missiles, and general purpose bombs. During the Korean Conflict, folding-fin aircraft rockets (FFARs), specialized antitank weapons, and fire-control systems were developed. By the end of the Vietnam War, efforts also encompassed laser-guided weapons and other "smart bombs," air-to-air and air-to-surface guided missiles, dispenser munitions, antiradar missiles, fuel-air explosives (FAEs), advanced antiship weapons, ship-launched guided missiles and projectiles, strategic weapons, aircraft guns, and swimmer/SEAL (Sea-Air-Land) weapons. Later, improvements were made in aircraft electronic warfare, avionics, and software, and by Operation Desert Shield/Storm, China Lake and Point Mugu technology had made a significant impact on nearly every aircraft and weapon system used, including Sidewinder, High-Speed Antiradiation Missile (HARM), Tomahawk, Rockeye, Sparrow, and Harpoon—along with the avionics to integrate and operate the weapons. The Bosnian war made use of the Advanced Medium-Range Air-to-Air Missile (AMRAAM), cluster bomb unit (CBU)-87, and CBU-99. JSOW and JDAM made their debut in Desert Fox. WD contributed significantly to these weapons. In Afghanistan and Operation Iraqi Freedom, U.S. and allied forces have relied heavily on many of these weapons and technologies. And Sidewinder still remains the world's premiere air-to-air missile.

WD Contributed to 50 Major Fleet Weapon Systems.

In addition to designing new weapons, WD is also upgrading and transforming existing weapons. Through the years, WD and its predecessor organizations developed and contributed to more than 50 major weapon systems and pioneered technologies that support the Fleet today.

HISTORY



China Lake. In the midst of World War II, the Navy established China Lake as the Naval Ordnance Test Station (NOTS) for testing and evaluating rockets being developed by the California Institute of Technology (Caltech). The formal mission statement for NOTS in 1943 identified "research, development and test of weapons" as the Station's primary purpose. This mission remains today. The first weapons included rockets and early missiles such as Mighty Mouse, Zuni, Sidewinder, and Shrike. In the 1950s, NOTS scientists and engineers developed the air intercept missile (AIM)-9 Sidewinder air-to-air missile, which has become the world's most used and most copied air-to-air missile. In 1967, China Lake combined with the Naval Ordnance Laboratory at Corona to form the newly created Naval Weapons Center (NWC). In 1979, the National Parachute Test Range (NPTR) at El Centro, California, also merged with NWC. In 1992, NWC China Lake joined the NAVAIR units at Point Mugu, California, and White Sands in Albuquerque, New Mexico, to become part of the Naval Air Warfare Center Weapons

Division (NAWCWD). Today, WD is headquartered at China Lake and is a tenant of the Navy Region Southwest.

On May 12, 2000, the U.S. Naval Museum of Armament and Technology was officially established at China Lake when the Secretary of the Navy signed the establishing memo, culminating a 10-year effort.

> "China Lake's notable accomplishments and famous desert culture have created an esprit de corps perhaps unequalled in the Navy's far-flung organization."
>
> —Dr. William S. Dudley
> Director of Naval History

The Museum contains one of the finest publicly accessible collections of tactical air weaponry and technology anywhere. The display collection ranges from WWII rockets to cutting-edge guided missiles and includes familiar items like Sidewinder, Shrike and Tomahawk alongside weapon systems that can be seen nowhere else—Agile, ACIMD, Bulldog and the Advanced Bomb Family (to name but a few). [2]

Point Mugu. The first Navy presence at Point Mugu occurred in 1946 when Seabees from Port Hueneme put down a Marsden Mat runway as the first airstrip. That same year, Point Mugu became the Naval Air Missile Test Center (NAMTC), the U.S. Navy's first instrumented missile-test sea range. NAMTC developed and tested missiles and drones, including the Gorgon, Gargoyle, Lark, and Little Joe. The Pacific Missile Range (PMR), headquartered at Point Mugu, was established in 1958. In 1959, NAMTC became the Naval Missile Center (NMC). Point Mugu, already home to the F-14 Tomcat System Integration Test Station, became host to the Software Support Activity for the Tomcat in 1971. As the Harpoon, Tomahawk, Trident, and Standard Missile were under test in 1975, the Navy merged PMR and NMC into the Pacific Missile Test Center (PMTC). In 1992, PMTC, NWC China Lake, and NAVAIR units at White Sands and Albuquerque, New Mexico, combined to form the NAWCWD.

On November 14, 2003, the Naval Base Ventura County at Point Mugu was formally named an American Institute of Aeronautics and Astronautics (AIAA) historic site because of its involvement in the development and testing of guided missiles. The institute designation placed it in the company of 20 other historic spots, including Kitty Hawk, N.C.; Dutch Flats, the San Diego airport where Charles Lindbergh's Spirit of St. Louis was tested; the Air Force Flight Test Center at Edwards Air Force Base, home of legendary test pilots and fledgling astronauts; and the Pasadena plant site where scientists for Aerojet Engineering invented rocket fuel in the 1940s. [3]

PEOPLE, RANGES, AND LABORATORIES

Dynamic Work Force. Today, more than 6,000 unique individuals continue the WD tradition. Close to 4,000 federal employees work side-by-side with more than 2,000 contractors, and military personnel, and 74% of the work force are in RDT&E competencies. WD is an efficient organization. Scientists, engineers, physicists, and mathematicians work on complex issues vital to national defense. Since 1959, more than 1,500 patents have been issued at WD. Some inventors hold more than 20 patents.

Innovative Management. July 2002 marked the 21st anniversary of the Navy's Joint Personnel Demonstration Project, which supports pay-for-performance rather than longevity. China Lake was one of two sites to test this new approach to personnel management. The Demo project has been closely scrutinized and has been so successful that Congress extended it twice and then permanently adopted it. The Demo now serves as a model for 16 other federal personnel projects.

> "I think we have some of the answers to that, Mr. Chairman, in the experiments that have already been conducted, thanks to the discretion the Congress has given us in the past. And I think that record shows that at key installations like China Lake where we have, perhaps, one of the best civilian work forces any country could ever have—private sector or government. It's produced some of the most remarkable technological breakthroughs. I think that flexibility in management has improved the capability of that civilian work force—has allowed us to keep the very best people around."
>
> —Paul Wolfowitz, Undersecretary of Defense
> From his testimony before the HASC during a hearing on May 1, 2003, on the Defense Department's proposed legislation to revamp the personnel system.

Enormous Ranges. WD's land, sea, and airspace are unique natural assets and are used for training and T&E. WD encompasses more than 1.1 million acres. The Land Range at China Lake is the Navy's largest single land holding, with 38% of all Navy land worldwide and 85% of the Navy's RDT&E land. The R-2508 restricted airspace, 12% of California's total airspace, includes more than 17,000 square miles over land. The Sea Range at Point Mugu includes 36,000 square miles of ocean (expandable to 196,000 square miles, from Big Sur south to the U.S./Mexico border). The R-2508 is

jointly managed by the Navy (China Lake), the Air Force (Edwards Air Force Base), and the Army (Fort Irwin).

Ranges are interconnected. For example, a unique FAA-approved restricted corridor (IR-200) connects the Sea Range with the Land Range to the north. This allows the launch of long-range Tomahawk cruise missiles from the Sea Range to targets on the Land Range, thereby allowing the Navy to test all operational aspects of the weapon system. Missiles are continuously monitored and tracked. They contain inert warheads, and chase planes can take control at any time.

Clear Weather for Testing. Both the Point Mugu Sea Range and China Lake Land Range airfields consistently enjoy great flying weather. Point Mugu is VMC (visual meteorological conditions) 85% of the time and China Lake is VMC 99.5% of the time—in other words, more than 360 clear days per year. Even Palm Springs, California, cannot match WD's meteorological statistics.

Facilities. WD has more than 40 major facilities, including three airfields, with a replacement value of close to $3 billion. More than 2,000 buildings encompass six million square feet. Many specialized facilities are not duplicated anywhere else.

The Sea Range off the coast of Point Mugu is the largest and most heavily instrumented sea and air range in the U.S. The Range Operations Center is capable of hosting and monitoring complex full battle group Fleet exercises involving aircraft, surface ships, and submarines. San Nicolas Island (SNI), 60 miles offshore, is used for littoral warfare training, including theater warfare exercises. SNI includes launching facilities and a 10,000-foot runway. At Point Mugu the Radar Reflectivity Laboratory (RRL) is the Navy's largest indoor radar reflectivity chamber, designated as a national asset. For more than 35 years, the RRL has helped determine what a target looks like to radar. The F-14 Weapons System Integration Laboratory supports software and avionics integration for the F-14A Tomcat aircraft and Phoenix missile systems. The Missile Systems Evaluation Laboratory is a $45-million facility with 123,000 square feet of special-purpose laboratories. This targets complex is the only facility to provide full life-cycle support for all Navy aerial and surface targets. The Surface Craft Division at Port Hueneme operates target boats and hulks and provides range surveillance and target recovery. Point Mugu's electronic warfare (EW) capability is a core area of expertise and supports the electronic attack (EA)-6B, the stand-off jammer aircraft for the Navy and the Air Force. It is the only dedicated tactical EW platform in the U.S. inventory.

At China Lake, the fighter/attack (F/A)-18 Advanced Weapons Laboratory (AWL) and the AV-8B AWL rank in the top 9% of the world's software developers. The Propulsion Laboratory is the Navy's one-stop shop for R&D of missile propulsion, ordnance, and fuzing. The Integrated Battlespace Arena (IBAR) includes nine modeling and simulation (M&S) laboratories, with secure links worldwide. The Missile Engagement Simulation Arena (MESA) hangs full-size jets like puppets, weighing up to 25,000 pounds, when testing missile fuzes. It is the only facility of its kind. The Skytop facility tests Trident and other massive rocket motors with up to one million pounds of thrust as well as rocket motors that produce only ounces of thrust. The Electronic Combat Range (ECR) realistically simulates combat threats. China Lake's Geothermal Plant turns a natural asset, volcanic steam, into usable electricity that helps power the base. And the Etcheron Valley Range, with mountains high in iron content, provides a perfect veil for testing high-powered GPS jamming; the Supersonic Naval Ordnance Research Track (SNORT) is a four-mile-long, dual-rail track, capable of propelling test items up to four times the speed of sound; and the new Live Fire Survivability Complex, when completed, will be the largest facility of its kind in the country.

Tenant Commands

Developmental Test and Evaluation

Air Test and Evaluation Squadrons (VX-30) at Point Mugu and (VX-31) at China Lake operate under the command of the Weapons Division and perform aircraft and weapons developmental testing and provide aircraft, aviators, and aircrew to support the RDT&E mission on NAVAIR's Sea and Land Test Ranges on the West Coast. They fly the F/A-18 Hornet, F-14 Tomcat, EA-6B Prowler, AV-8B Harrier, attack helicopter (AH)-1 Cobra, and HH-1 Huey in support of weapon systems integration and sustainment. They also fly the NP-3D Orion, C-130 Hercules, T-39 Saberliner, and QF-4 Phantom in support of "systems under test" on NAVAIR's test ranges; pilots log more than 10,000 hours of testing and training missions annually. [4]

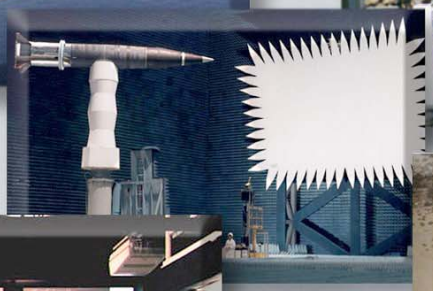
Operational Test and Evaluation

Air Test and Evaluation Squadron Nine (VX-9) conducts operational test and evaluation of all air-to-ground weapons, air-to-air weapons, and software upgrades to aircraft and weapon systems. More than 240 VX-9 Vampires support approximately 16 aircraft for the independent test and evaluation community. The squadron headquarters is at China Lake, with a detachment at Point Mugu. VX-5 moved to China Lake from Moffet Field in 1956, and merged with VX-4 from Point Mugu to become VX-9 in 1995 under the Commander Operational Test and Evaluation Force (COMOPTEVFOR). [4]

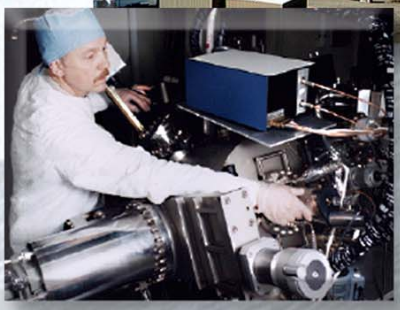
Marine Aviation Detachment (MAD) provides project management, aviation support and technical expertise for assigned Marine Corps weapons systems, subsystems, and mission planning at both China Lake and Point Mugu. Marines assigned to the MAD support multiple RDT&E missions, to include VX-31, and operational test and evaluation at VX-9. The MAD is headquartered at China Lake. MAD was established in 1988 but Marines have been stationed at China Lake since 1943. The MAD operates under the command of the Aviation Department Headquarters, Marine Corps. [4]

Laboratories & Facilities








WHAT THE NAVAIR WD DOES BEST

Aircrew Safety and Survivability. Since the 1950s, aircrew safety and survivability have been central to the technical mission of the National Parachute Test Range (NPTR) that was relocated to China Lake in 1979. It was here that the rocket-assisted personal ejection catapult (RAPEC) was designed, developed, tested, and released. RAPEC and subsequent systems have saved the lives of hundreds of aircrew members.

Systems such as the Navy Aircrew Common Ejection Seat (NACES) and China Lake developed and produced Thin-Pack Parachute (now deployed in Fleet patrol (P-3 Orion aircraft) are of incalculable value in increasing the survivability of military aircrew members. Related efforts conducted at state-of-the-art survivability facilities have led to major improvements in the ability of U.S. aircraft to survive the harsh environment of air combat and bring their crews safely home.

Following the *Challenger* disaster in 1986, China Lake worked with NASA in the evaluation of an emergency escape system for the Space Shuttle. Military test parachutists tested the system from a specially modified Convair-240 aircraft. Scientists and engineers assisted NASA's Pathfinder team by testing the rocket-assisted deceleration (RAD) system as well as designing and fabricating the actual tether system between the RAD and the landing package that was used in the successful Pathfinder landing on Mars in 1997.

During the Mars Exploration Rover (MER) mission in 2004, China Lake designed, built, and assisted in installing the bridle system onto both spacecraft; designed the descent rate limiters (joint effort with JPL); tested the radar systems that were used in timing airbag deployment and retro-rocket ignition; tested the retro-rockets that slowed both landers descent; and conducted multi-body tests involving the parachutes, back-shells, and landers.

Avionics. Avionics integrate a weapon-delivery platform—the aircraft—with its weapons and sensors. From development of the FLIR system, which produced the first-ever 24-hour attack capability, to today's cutting-edge avionics on the F/A-18E/F Super Hornet, WD has played a central role in making avionics one of the chief reasons for U.S. supremacy over its adversaries.

Complex Weapon System Integration. Key aircraft platforms in the current war include the F/A-18, F-14, EA-6B, and AV-8B. WD has Weapon System Support Facilities for F/A-18, F-14, EA-6B, AV-8B, and the AH-1 helicopter. WD also integrates the mission avionics for the special missions EP-3E, supports development of the Joint Strike Fighter (JSF), and supports the Air Force F-22 in Sidewinder weapons integration. WD supports the system design and development phase of the JSF and staff provides systems and software engineering and integration, primarily in the mission systems (avionics) and weapons integrations areas. WD also performs JSF live fire testing, integrated test force, verification and survivability activities.

For the past 20 years, WD has been a world leader in integrating highly complex weapon systems, including the avionics and EW equipment, into naval aircraft. As an example, the F/A-18, the Navy's strike fighter, forms the core of the Navy's air warfare capability. F/A-18s use numerous mission computers with more than 10,000,000 words of code in more than 40 processors. The new F/A18-E/F Super Hornet now has 11 weapon stations and increases weapons carriage, fuel load and range, growth space, and survivability. [5]

The Advanced Weapons Laboratory (AWL) at China Lake is responsible for integrating the weapons, avionics, sensors, EW systems, FLIR, software, and radars into the F/A-18. This laboratory reached the Software Engineering Institute's (SEI) Level 4. This prestigious rating puts AWL in the top 9% of the world's software developers.

Weapons integrated include free-fall bombs (Mk 80 series), foreign and domestic short-range missiles (ASRAAM, Python, AIM-9 series to include AIM-9X), AMRAAM, Sparrow, JSOW, JDAM, SLAM-ER, Maverick (EO and IR), HARM (to include Block 3A/5/6 and the QuickBolt and AARGM series), and the M-60 gun. [6]

In September 2002 the AV-8B Joint System Support Activity (JSSA) achieved the SEI Software Capability Maturity Model (SW-CMM) Level 4. JSSA now ranks in the top 9% of all organizations assessed.

The SEI at Carnegie Mellon University has carefully scrutinized the advanced software practices of more than 1,100 private and government agencies, including Boeing, Raytheon, and Warner Robbins AFB. In an exhaustive process involving more than 4,300 pages of documentation, more than 30 in-depth interviews and five days of on-site assessment, companies are ranked in several areas of technical expertise, including software product engineering, quantitative control processes, software quality processes, and organizational process focus and definition.

Weapon Platform Integration

Electronic Warfare. The EA-6B Systems Integration Facility is the only existing Airborne Electronic Attack (AEA) facility of its kind. Point Mugu has been the center of AEA research, design, and test since 1968.

Point Mugu has eight specialized laboratories. The Prowler's radar and communications-jamming capabilities continue to lead the way in neutralizing enemy air-defense systems in the early days of battle, allowing U.S. fighters free use of the skies. Since 1990, most strike groups insist on the protection of an AEA umbrella. The EA-6B provides cover for the entire strike group, allowing offensive craft to penetrate safely within lethal range of ground missiles and radar. Also at Point Mugu is the Radar Reflectivity Laboratory, the Navy's largest indoor radar reflectivity chamber. Engineers develop, test, and integrate radar warning systems, jammers, decoys, and software. In addition, WD designs, fabricates, and tests the aerodynamic, mechanical, electrical, and structural interfaces.

EW facilities at China Lake include the ECR, the Navy's principal open-air range for T&E of airborne electronic combat. In realistic training just short of actual combat, pilots can fly against simulated air-to-air threats, and surface-to-air threats and complete an air-to-ground strike all in a single mission. The Etcheron Valley Range provides a perfect venue for testing directed energy weapons technology and GPS packages in jamming environments without disturbing commercial or military aircraft.

Energetic Materials. Explosives RDT&E has included developing explosives, warheads, shaped charges, and castable explosives; ordnance safety; ordnance-pollution abatement; and characterization of metals under explosive loading. China Lake was the first to develop plastic bonded explosives (PBX).

Propellant RDT&E began with a concentration on double-base propellants and expanded into work on liquid, smokeless, and alternative solid propellants; combustion instability; manufacturing and storage applications; material and system safety; and liquid, solid, ramjet, and hybrid propulsion systems. China Lake propellant work has also found application in space programs, weather modification, and ejection systems. And China Lake was the first to synthesize the CL-20 energetic molecule, one of the most significant energetic ingredients in the past 50 years.

Thrust-vector-control technology developments have provided the foundations for numerous weapon applications, including vertically launched weapons, and highly maneuverable air intercept weapons. China Lake also refined and developed advanced processes and technologies for explosive forming and welding of metals that revolutionized the industry.

Full-Spectrum Fleet Support. WD is intimately involved with a product from cradle to grave—from concept formulation through research, development, manufacturing support, Fleet support, weapon retirement from service; and environmentally compatible system demilitarization.

Fuzing. Advances in fuzing technology at China Lake and its predecessor organization at Corona, California, provided the Navy with a world-class design capability in target-detecting devices (TDDs), contact sensors, electromechanical safety and arming (S-A) devices, and fuze antennas, with hundreds of designs and components in Fleet use. Highly advanced fuze documentation is in widespread use by many North Atlantic Treaty Organization (NATO) countries. Guided-missile warhead fuzes cause the weapon to detonate at the point where the explosion will do the most damage. Fuzes are critical to weapon success.

Fuzes—Key Elements of War

Since post-WWII, when the U.S. Joint Chiefs of Staff listed the atomic bomb, radar, and the proximity fuze as the three most significant developments of the war, China Lake has been developing fuzes and components. [7]

Concerning safety and arming (S-A) devices, China Lake has nearly three quarter of a million devices in the Fleet with an outstanding safety record. S-A devices are in use in all Navy guided missiles. Development began in 1953 and continues today. China Lake developed a universal arming and firing device to remotely safe and arm rocket motor ignition devices. S-A devices ensure safety in missile handling, shipping, storage, and launch. The S-A device is a fuze component that isolates the detonator from the warhead booster charge until the launched weapon has achieved a safe distance. [7]

Presidential Citation

On December 16, 1964, President Lyndon Johnson presented a citation to a team of China Lake/Corona engineers for greatly improving the efficiency/economy of S-A devices by improving operation and reliability and reducing their weight, size, and cost. The new S-A was adapted to almost all Navy missiles. Costs savings for the first procurement exceeded 20 million dollars, and the cost savings since then has far exceeded one billion dollars. [8]

Continuous-slot antennas optimize warhead burst time while also improving countermeasures. The Mk 45 TDD for

Standard Missile, an example of this expertise, is considered by many to be the world's premier missile fuze. [7]

Free-fall weapon fuzing work includes the fuze munitions unit (FMU)-140/B dispenser proximity fuze, the DSU-30/B TDD and the FMU-139/B electronic bomb fuze, which increased the reliability of bomb fuzes up to 97% versus 75%. Between 1980 and 1990 more than one million of these fuzes were delivered. [8]

Edge-detection was developed in the mid-1960s and is now used in most Navy anti-air missiles. Edge detection increases the probability of detonating the warhead while the target is within its lethal range, in contrast to a simple timed detonation. [7]

Fore-and-aft adaptive-logic was developed at China Lake and used in long-range missiles. This extension of edge detection uses two beams instead of one. As the missile approaches a target, it size changes from a dot to an extended shape, and the two beams help determine the target size and the optimum time to detonate the warhead. [7]

Pseudorandom-noise modulation was applied to TDD designs to take advantage of spread spectrum techniques in which the transmitted signal is spread over a wide frequency band, providing a lower-density signal than conventional signals. For fuzing applications, it makes the signal difficult to detect, while providing a high-resolution target-detection capability. [7]

Active-optical fuzing, is now used in TDDs for anti-air and anti-surface missiles. TDDs use an active source, usually a laser, to detect the target. The active optical TDD provides high-range resolution information and narrow-beam control, improving the ability to place the warhead fragments on the target. During the Vietnam Conflict, a crash program was begun in 1968 to develop an active optical TDD; China Lake produced the DSU-10/B in eight months. [7]

Laser and Optical Components. China Lake developed optical-component polishing and coating techniques, optics evaluation and instrumentation, surface-absorption measurement, and surface-damage characterization. Accomplishments in laser research range from early development of a night search-and-rescue system that grew out of dye-laser research to the development of the diode laser. Developments also include the interferometric surface scanner; bowl-feed polishing, ultra-high-vacuum deposition, and ultra-clean sputter-deposition optical-film-production techniques; and a portable CO_2 laser.

Modeling and Simulation (M&S). WD's earliest use of M&S was in the creation of analog and digital simulations for weapon systems. Weapon System Support Activity (WSSA) laboratories integrate advanced weapons and components into a total weapon system onboard naval aircraft platforms. M&S plays a major role in this integration process allowing continuous design assessment throughout the process. In the past, live fire testing had been exclusively used to evaluate how a missile system functions. WD pioneered simulation based acquisition (SBA).

The use of M&S during development has saved tens of millions of dollars over the years. Using hardware-in-the-loop (HWIL), WD integrates part of the missile hardware, such as the seeker or control section, into the simulation, running in real time. Part of the missile functions in the laboratory as though it were in actual flight. During the 1970s and 1980s, HWIL reduced the number of live firings required to field Sidewinder, Sparrow and RAM. In the 1960s the AIM-9D required 129 live firings to prove out its performance. By 1981 the AIM-9M required only 35 live firings. Total acquisition risk was also significantly reduced because extensive use of HWIL simulations solved design problems early in the developmental cycle when they could be fixed at a much lower cost with much less schedule impact.

During the 1990s WD developed signal-processor-in-the-loop (SPIL) advanced simulations made possible by high performance computers and custom digital processors. SPIL creates very complex target scenes, including a detailed model of the seeker front end, and then injects the seeker sensor output directly into the real missile signal processing hardware. SPIL significantly contributed to the Sidewinder, Sparrow, RAM, and SLAM programs. Simulations also allow engineers to better understand threat missile systems, particularly the man portable air defense systems (MANPADS), against our own aircraft.

Today, WD uses advanced simulation technology to link geographically separated facilities such as the Integrated Battlespace Arena (IBAR), global positioning system (GPS) Laboratory, and F/A-18 Advanced Weapons Laboratory (AWL) at China Lake; the Interoperability Test and Evaluation Complex (ITEC) at Point Mugu; and the Air Combat Environment Test and Evaluation Facility (ACETEF) at Patuxent River into a total "virtual" battlespace. [9]

Test, Evaluation and Training. Each year WD conducts more than 3,000 test events, close to 300 major training events, and about 2,000 training sorties. WD evaluates weapons, components, and systems in realistic environments; conducts full-scale, joint-live-fire survivability testing; and tests guns and ammunition, explosives, and propellants. WD can safely detonate up to 500,000-pounds of explosives without public complaints. Other testing activities include GPS jamming, high power microwave, and firefighting agents and devices. WD maintains the world's largest collection of "shootable" antiradiation missile targets for test activities. WD conducts extensive modeling and simulation in numerous specialized facilities; and China Lake has served as the National Parachute Test Range (NPTR) since 1979.

Training the Fleet. WD also helps train the Fleet—from simple to complex. WD can support anything from one aircraft on one target to complex battlespace scenarios involving multiple sites and multiple players. Fleet Training Exercises, and Fleet Battle Experiments, FBEs, are becoming increasingly complex, and WD is becoming more involved.

Since the late 1990s, WD has been involved in eight major exercises. Each year, the Division conducts complex "what if" battle group scenarios to see how well all the weapons systems play out in real time. The goal is to see what works and what doesn't. In 2002, WD completed the Millennium Challenge, named FBE-Juliet. The Sea and Land Ranges were the site of live action by joint forces.

Efforts were orchestrated from the Interoperability Test and Experimentation Center at Point Mugu, and the Integrated Battlespace Arena at China Lake.

Each year, allied customers from many nations send hundreds of troops to train for conflict and test weapons on WD's ranges.

Allies include Australia, Canada, Great Britain, Switzerland, Italy, and Norway. The Japanese are one of WD's largest customers on the Sea Range.

At Superior Valley, WD has tactical targets and automatic weapon scoring systems where WD trains pilots, including F/A-18 squadrons from Lemoore. WD also conducts search-and-rescue training and helicopter mobile assault training. And on the Electronic Combat Range, pilots can fly against actual threat radar systems. They can fly HARM missions, practice tactics, and use countermeasures.

Warhead Design. Since the 1950s, China Lake has served as the warhead design agent for most Navy missiles and free-fall weapons, providing quick response production. Examples include **Anti-surface weapons:** Harpoon, Tomahawk, Penguin, Maverick, Condor Shrike, HARM, Standard Antiradiation Missile (ARM), SLAM-ER, Air Launched Tacit Rainbow, Ground Launched Tacit Rainbow, and Zuni 5.0-Inch Rocket. **Free Fall Weapons:** Bombs, Skipper, Walleye, Rockeye, APAM, Fuel Air Explosive (FAE), and FAE II. **Anti-Air Weapons:** Rolling Airframe Missile (RAM), Sparrow, Sidewinder, and AMRAAM. [10]

Future Technologies in the News. Many articles have detailed WD innovative technologies and advances. Articles have appeared in publications, including *Aviation Week and Space Technology*, *Smithsonian Air & Space Magazine*, *Popular Mechanics*, *National Defense Magazine*, *Wall Street Journal*, *New York Times*, *Los Angeles Times*, *Bakersfield Californian*, and *Government Executive Magazine*. Television broadcasts have included Dateline NBC, 60 Minutes, and Discovery Channel.

Warfighter Requirements

For a few examples of how WD continues to respond quickly to warfighter requirements, please see the Index: *Requirements, Warfighter,* Page 157.

Awards, Testimonials, VIP Involvement

For a complete list, please refer to the Index.

Awards: Page 151.

Testimonials/VIP Involvement: Pages 158 and 159.

Smart Buyer. WD has traditionally worked closely with contractors by ensuring the government's and taxpayer's interests are served during system development. To be most effective, this "smart buyer" function requires active, hands-on involvement by laboratory personnel.

For example, to prosecute the war on terrorism, U.S. warfighters needed a hard-target penetrating warhead. The contractor for the BLU-116A/B Hard Target Deep Penetrator changed its initial proposal, offering to produce only 250 (rather than the original 420) for $29 million. The Defense Threat Reduction Agency turned to China Lake, which ended up with a $25 million contract to redesign and produce a minimum of 370 of the warheads. And when the contractor-designed FMU-159A/B hard-target smart fuze (HTSF) for the BLU-116 could not be produced with the desired reliability under a tight delivery schedule, China Lake was asked to solve the problem with an alternate fuze—a modified FMU-143—that is being qualified for use in the new warhead.

Again, when the Harpoon antiship missile twice failed operational evaluation in 1976, China Lake was tasked to correct the problems. Civil-service engineers conducted a thorough review of production processes and then put together a comprehensive support plan involving, among other steps, integrated factory testing, product assurance upgrades, production data package validation, physical audits, and construction of a factory-equivalent test facility.

The payoff began to show in the following year. Costs dropped, factory acceptance yields climbed, and the maintenance-due date was extended from two to three years.

There was not a single free-flight failure of a Harpoon seeker built after the corrective actions.

> "China Lake is a jewel in our crown. We have depended on it to help in leading us into second sourcing. It shows the value of keeping a good base of development going outside of industry and inside of the services."
>
> —Hon. John Lehman Secretary of the Navy
> Before the House Armed Service Committee,
> March 5, 1986.

Also, in 1971 when severe quality problems were plaguing the AIM-7F Sparrow missile, NAVAIR asked China Lake to find a solution.

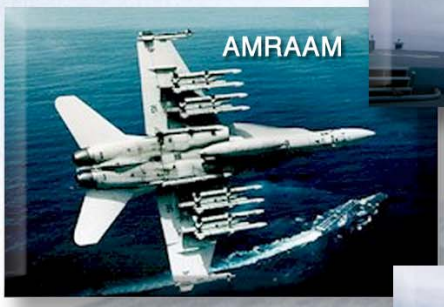
In-house engineers took custody of the baseline documentation from the single Sparrow contractor and set up an in-house missile subassembly test capability. They invoked stringent production-assurance processes at the contractor plant and began opening competition to a second source. The baseline for both contractors was rigidly controlled with configuration audits and technical and documentation reviews.

The result was that a program out of control in terms of cost and quality was, over a period of three years, brought back into line. Mean time between failures (a measure of reliability and quality) soared, and over the next 10 years, the cost for the guidance-and-control section dropped from $300 thousand per unit to less than $100 thousand. [10]

Cost Savings, Best Business Practices

For a complete list, please see the Index: *Cost Savings, Best Business Practices*, Page 152.

Family of Weapons



FAMILY OF WEAPONS

WD expertise has been applied in the majority of the U.S. family of air-, surface-, and sub-surface-launched weapons. The current family includes AMRAAM, JDAM, JSOW, Sidewinder, HARM, Trident, Tomahawk, RAM, Standoff Land-Attack Missile–Expanded Response (SLAM-ER), and ESSM. Through the years, WD has played every role in weapon development. Currently WD is working directly or indirectly on 25 different weapons and weapons systems for the Fleet. WD is the primary technical lead for 15 systems, and we provide other engineering or T&E support to dozens of other weapons, projects, and programs.

Pioneered Technologies That Influence Today's Military Arsenal.

- Precision guidance in IR–Sidewinder missile.
  Invented and developed the Sidewinder missile.
- Antiradar (passive RF) guidance–Shrike, HARM, AARGM. China Lake developed Shrike, which begat HARM.
  Developed the HARM low-cost seeker.
- TV guidance. China Lake developed Walleye, the archetype of all modern TV-guided weapons.
- Technologies for proximity fuzing, warheads, solid rocket propulsion, and thrust vector control (TVC).
  TVC is currently used on SeaSparrow, Tomahawk, VLA, AIM-9X Sidewinder, and Standard Missile.
- A systems approach to weapon integration on naval platforms versus integrating weapons as an "afterthought."

Conflict Involvement. In Kosovo, China Lake and Point Mugu influenced HARM, JDAM, JSOW, and Tomahawk weapons. During Desert Shield and Desert Storm, China Lake re-invented the FAE weapon to help clear minefields for the Marines. In addition, the Center conceived and developed the Sidewinder missile, the world's most accurate, reliable, and successful dogfight missile, along with Walleye, Shrike, FAE weapons, FFARs, forward-looking infrared (FLIR) technology, and the "Eye" series of free-fall weapons.

> A survey by the Office of the Chief of Naval Material rated China Lake the top Navy Laboratory in the 1970s. China Lake developed more than 75% of all air-to-air and air-to-ground weapons used in combat in Vietnam.
>
> — Robert McNamara, Secretary of Defense

In the Korean War China Lake produced and delivered the 6.5-inch tank-killing rocket, RAM, to Korea in just 29 days; the Michelson Laboratory hall was turned into a crash production facility for RAM fuzes. In WWII, China Lake developed, tested, and trained pilots and crews to fire the aircraft rockets and bombardment rockets that affected the outcome of the war.

QUICK FLEET RESPONSE ACHIEVEMENTS

Operation Iraqi Freedom (OIF). Since 1943, China Lake and Point Mugu have demonstrated a quick-response capability that has saved lives, equipment and money. Quick response depends on a close operating relationship between the Fleet and WD.

80% Weapons—WD Influenced

WD supported the integration and development of more than 80% of the weapons used in theater during Operation Iraqi Freedom. Weapons included JSOW, JDAM, HARM, Tomahawk, SLAM-ER, LGB/GBUs, and AMRAAM.

WD accelerated and deployed the F-14D Operational Flight Program (OFP) D04 software to all F-14D squadrons on three carriers in two oceans in three weeks. F-16 JDAM software was quickly tested on the China Lake Ranges before it could be sent back to Iraq. In addition, the F/A-18 shared-reconnaissance pod (SHARP) development was accelerated and approved for early deployment. WD's Warfighter Response Center was manned around-the-clock resolving difficult issues for the Navy, Marine Corps, Army, and Air Force. For example, an Air Force pilot experienced some problems dropping a particular weapon in theater. Within hours WD engineers were testing a proposed solution on the land range. That same day, the fix was on its way. "And as F-16s flying missions in Operation Iraqi Freedom were having problems delivering their munitions, experts at Hill AFB, Utah; Edwards AFB; and NAWCWD, China Lake, California, worked together and found a fix an amazing 30 hours later. That's the kind of warfighter support our Air Force wants, needs, and continues to get." General Greg Martin, Commander, Air Force Reserve Command, Wright Patterson AFB, Ohio.

WD also designed, developed, and built a new metal augmented charge (MAC) warhead for the Hellfire Missile. The effects are formidable. [21]

> "[The Hellfire] can take out the first floor of a building without damaging the floors above, and is capable of reaching around corners, into niches, and behind walls to strike enemy forces hiding in caves, bunkers, and hardened multi-room complexes. It went from development to deployment in less than a year."
>
> —Donald Rumsfeld, Secretary of Defense

QUICK-RESPONSE ACHIEVEMENTS

Operation Enduring Freedom (OEF). JDAM and JSOW refinements and upgrades were accelerated as were F-14B OFPs, F/A-18 software block upgrades, and new electronic warfare (EW) suites. In addition, range testing and training activities were accelerated, involving the Tomahawk, Hellfire, AMRAAM, JSOW, and Harpoon. Point Mugu provided round-the-clock support with the EA-6B Prowler Program.

China Lake also invented and developed the Tactical Dissemination Module (TDM), a revolutionary new portable computer/radio system that creates customized real-time-targeting strike packages for specific aircraft. For example, a special operations force identifies a time-critical target. Next, they digitally photograph the target, determine the approximate global positioning system (GPS) coordinates, and then transmit the data back to Central Command (CENTCOM), who decides which weapon is currently available (target weapon pairing), in order to make the call for fire (CFF).

Baghdad International Airport

During Iraqi Freedom, as coalition forces captured Baghdad International Airport, the Forward Dissemination Element (FDE) was immediately relocated there for the duration of the conflict. TDM supplied more than 900 target packages to coalition bombers and is still forward-deployed. TDM is scheduled to be installed on six U.S. Navy ships in FY04. [60]

Kosovo. Navy, Air Force, and allied aircraft fired more than 1,000 HARMs during the air campaign in Kosovo. A HARM Tiger Team from WD deployed to Italy to support forward-deployed forces. The team reloaded up-to-date missile software in more than 400 missiles in 36 days. HARM subject matter experts provided on-site training and technical support. When additional mission scenario data was needed, to allow HARM to attack new threats, WD accelerated development and deployed it to the Kosovo Theater in less than four weeks.

Quick-Response Achievements

For a complete list, please see the Index: *Quick-Response Achievements* Page 156.

Desert Fox. A rapid response was provided to deployed forces onboard *USS Nimitz* in the Persian Gulf. The response provided military technicians with new maintenance tools designed and built by F/A-18 Facilities Task Team personnel. In addition, Carrier Air Groups (CAGs) deployed in support of Operation Desert Fox urgently requested some of the first-production JSOW air-to-ground missile (AGM)-154A assets in support of operations. WD studied the feasibility, identified software incompatibilities, prescribed a fix, and conducted testing in the F/A-18 AWL at China Lake. WD quick-response team was formed and traveled to McAlester Army Ammunition Plant, Oklahoma, and reprogrammed JSOWs with software compatible with the deployed system.

Desert Storm/Desert Shield. China Lake and Point Mugu responded with quick-reaction, on-demand requests to support operating forces and troops in the Persian Gulf. Engineers modified, improved, tested, and validated various aspects of the Sidewinder, Tomahawk, FAE, HARM, and Shrike weapon systems. Point Mugu also developed EW system upgrades, developed and hand-delivered OFP upgrades, and developed and fielded weapon-integration and weapon-targeting software for combat aircraft.

Vietnam Conflict. During the Vietnam Conflict an immediate need arose for a specialized TDD for the Standard ARM (antiradiation missile). In only eight months, China Lake/Corona developed and fielded a new active-optical TDD, the DSU-10/B. In addition, through the Vietnam Laboratory Assistance Program (VLAP), China Lake provided scientific/technical advisors to the Fleet and the Marines tasks were of a quick-response nature: quick fixes, typically inexpensive, to emergent problems. Some 50 tasks were addressed by China Lake personnel. Included were a small beacon for use by ground troops in identifying themselves to A-6 attack aircraft (1968), map illuminators (1969), hand-emplaced FAE canisters for mine clearance (1970), and a lightweight gun pod for the Marines. China Lake also provided direct support to the Special Forces community with custom explosives and devices, night-vision signals and devices, and specialized weapons and grenades, communications gear, and unique support equipment.

Cuban Missile Crisis. In 1962 the Soviets had set up medium-range nuclear missiles in Cuba with complicated arrays of radar defending missile sites. The U.S. had no antiradar missile, but Shrike was under development at China Lake. An urgent message was received to provide Shrike missiles at once, even though the development program was not completed. Two hundred missiles were built, about half produced in-house at China Lake.

Korean War. During the Korean War an urgent request came from the field for a weapon to defeat 13-inch tank armor. Within 29 days China Lake developed a shaped-charge warhead to match with the five-inch high-velocity aircraft rocket (HVAR) motor and produced RAM, a 6.5-inch Antitank Aircraft Rocket (ATAR). RAM was designed, tested, documented, and produced at China Lake, and put in service in Korea.

WWII. In WWII the Navy-Caltech team at China Lake created "Holy Moses," one of the most effective and widely used U.S. rockets of war.


Iraqi Freedom
2004
Enduring Freedom
2001
Kosovo
1999
Desert Fox
1998
Bosnia
1992-1995
Arming The Fleet
Desert Shield/ Storm
1991
Vietnam
1956-1975
Korea
1950-1953
WWII
1941-1945


CAPTURED

ARMING THE FLEET

Table of WD-Influenced Weapons in Conflict

During every major U.S. military crisis since WWII, RDT&E work at China Lake and Point Mugu, has played a significant role: developing and testing weapons and systems that work!

✓ = Active Fleet Inventory

◯ = Used in Combat

	Iraqi Freedom (2003-Present)	Enduring Freedom (2001-Present)	Kosovo (1999)	Desert Fox (1998)	Bosnian Conflict (1992-1995)	Desert Storm (1991)	Vietnam Conflict (1956-1975)	Korean War (1950-1953)	World War II (1941-1945)
AMRAAM	✓	✓	◯	◯	◯	✓			
ASROC / VLA	✓	✓	✓	✓	✓	✓	✓		
Atomic Weapon Non-nuclear components									◯
FAE	✓	✓	✓	✓	✓	◯	◯		
Fleet Ballistic Missiles	✓	✓	✓	✓	✓	✓	✓		
Gator		✓	✓	◯	✓	◯			
General Purpose Bombs	◯	◯	◯	◯	◯	◯	◯	◯	◯
HARM	◯	◯	◯	◯	◯	◯			
Harpoon, SLAM, SLAM-ER	◯	◯	◯	✓	✓	◯			
Hellfire	◯	◯	◯	◯	◯	◯			
JDAM	◯	◯	◯						
JSOW	◯	◯	✓	✓					
Laser Guided Bombs	◯	◯	◯	◯	◯	◯	◯		
Maverick	◯	◯	◯	◯	◯	◯	◯		
Phalanx	✓	✓	✓	✓	✓	✓			
Phoenix	✓	✓	✓	✓	✓	✓			
Rockets	◯	◯	◯	◯	◯	◯	◯	◯	◯
RAM	✓	✓	✓	✓	✓				
Shrike	✓	✓	✓	✓	✓	◯	◯		
Sidewinder	✓	✓	✓	✓	◯	◯	◯		
Skipper						◯			
Sparrow, Sea Sparrow, ESSM	✓	✓	✓	◯	✓	◯	◯		
Standard Missile	✓	✓	✓	✓	✓	✓	◯		
Tomahawk	◯	◯	◯	◯	◯	◯			
Walleye	✓	✓	✓	✓	✓	◯	◯		

NOTE: Middle East and Falklands, Iran/Iraq War, Cuban Missile Crisis - Although direct combat involvement by U.S. Navy forces was either minimal or advisory, many of the weapons and systems developed and tested by China Lake and Point Mugu and deployed by the Fleet were used as deterrents during these conflicts. [11]

AMRAAM

Definition. The AIM-120 Advanced Medium-Range Air-to-Air Missile (AMRAAM) is an all-weather, beyond-visual-range, supersonic aerial-intercept guided missile that uses active radar target tracking and target detection and proportional navigation guidance. With its sophisticated avionics, high closing speed, and excellent end-game maneuverability, the chance of escape for an AMRAAM's target is minimal. Upon intercept, an active-radar proximity fuze detonates the high-explosive warhead to destroy the target. AMRAAM is used against a wide array of air targets, with emphasis on destroying threat air-superiority fighters. Once the missile closes in on the target, its active radar guides it to intercept. This enables the pilot to aim and fire several missiles simultaneously at multiple targets and perform evasive maneuvers while the missiles guide themselves to the targets. AMRAAM is a follow-on to the AIM-7 Sparrow missile.

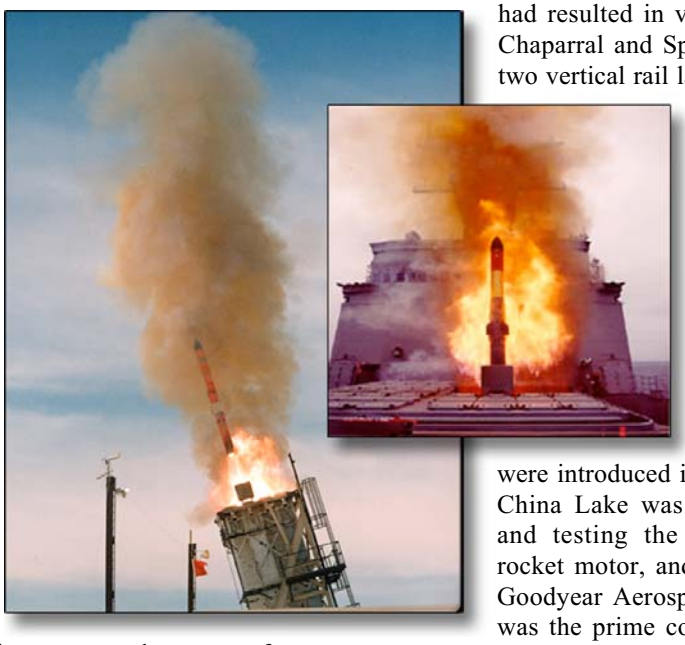
WD Initial Role. The AIM-120 AMRAAM began with a joint U.S. Air Force/Navy program in 1975 to enhance missile performance in the 3- to 40-mile range. AMRAAM was designed to improve upon the AIM-7 Sparrow missile. AMRAAM has smaller wings, greater range, and improved reliability and is lighter than the AIM-7. AMRAAM is a joint Air Force (lead service) and Navy program. Raytheon is the contractor. WD supported AMRAAM with developmental testing and performance evaluations, operational testing, reliability assessments, aircraft-integration testing, Fleet introduction, and logistics support. During full-scale development, more than 200 test missiles were launched from three sites, including Point Mugu. WD provided systems engineering, guidance, fuzing, system safety, propulsion, insensitive munitions, vulnerability, aircraft interface, logistics support, and cost analysis for the Navy. Initial operating capability for the Air Force was declared in 1991 and for the Navy in 1993.

AMRAAM in Conflict. During **Operation Iraqi Freedom**, Point Mugu teams reprogrammed AMRAAMs with updated software. In 2001 and 2002, during **Operation Enduring Freedom**, WD helped integrate AMRAAM on the F/A-18E/Fs for Coast Patrol (Homeland Defense) as well as for the Spanish and Italian AV-8Bs. During **Kosovo**, AMRAAMs were used to shoot down six Serbian MiG-29s. During the **Bosnian Conflict,** AMRAAM was deployed on F/A-18, F-15, and F-16 fighters with one Galeb kill over Bosnia. In December 1992, an F-16 pilot fired the first AMRAAM in actual combat, shooting down a MiG-25 Foxbat during a confrontation over southern Iraq. In **Operation Southern Watch**, AMRAAM scored two kills.

WD Current Role. WD's current role includes development and engineering support, test and evaluation, platform integration, Fleet logistics, Fleet training, and other technical support. WD executes the Navy Combat Archer program, which provides AMRAAM Fleet training, tactics assessment, and inventory monitoring data. WD supports approximately 20 AMRAAM firings each year and an overall total of 150 air-to-air training launches during eight to 10 Fleet exercises each year. WD integrated the AMRAAM Captive Equipment (ACE) and Integration Test Vehicle pods on the F/A-18s. WD supported Navy/ Air Force follow-on test and evaluation, achieved electronic classified delivery of software to the Fleet, and supported numerous product improvements. The first guided AMRAAM shot from an F-22 took place on the Sea Range, and the AV-8B Harrier launched its first AMRAAM at WD. The British used the Sea Range to test the AIM-120B on their F/A-2 Sea Harrier. Using captive flights and digital and hardware-in-the-loop simulations, WD continues to evaluate the combined F/A-18/AMRAAM system against a variety of threat electronic attack systems. WD helped develop the capability that permits missile software to be reprogrammed onboard all U.S. carriers and worked closely with Foreign Military Sales (FMS) AMRAAM customers, including Switzerland, Australia, Italy, and Spain.[12]

ASROC/VLA

Definition. The Antisubmarine Rocket (ASROC) is a quick-reaction, all-weather, intermediate-range, Antisubmarine Warfare (ASW) weapon launched from surface ships. ASROC consists of a torpedo, a double-base propellant rocket motor, an ignition separation assembly, and a dome-shaped plastic nose cap that protects the torpedo's transducer assembly as the weapon enters the water. Vertical Launch ASROC (VLA) is an improved rocket-propelled, ASW weapon designed for deployment on ships equipped with the Mk 41 Vertical Launching System. VLA uses a larger rocket motor with a jet-vane thrust vector control (TVC) system and an on-board digital autopilot to ensure accurate, extended-range delivery from the vertical-launch mode. The VLA delivers both the Mk 46 Mod 5 Torpedo and the Mk 50 Advanced Lightweight Torpedo against threat submarines at intermediate ranges.



WD Role. After WWII, the Navy began to seek means of extending the range of ASW torpedoes. In 1952, China Lake conducted feasibility studies on the Rocket-Assisted Torpedo and conducted tests with rocket-propelled depth charges. The two programs were combined as ASROC. In June 1956, a support contract was awarded, and in 1961 the system became operational. ASROC has since been used extensively by the U.S. Navy and Allied fleets.

Extended Range ASROC (ERA). The ERA Program began in 1964 to upgrade ASROC by doubling the missile's standoff range and increasing delivery accuracy. The ERA Program increased the motor size; substituted a modern, cast aluminized composite propellant; and added a secondary injection TVC system. China Lake formulated the new propellant, developed rocket motor cases, processed and loaded motors, and integrated the TVC system. The NOTS Pasadena Annex provided airframe and torpedo components. When upper atmospheric winds negatively affected accuracy, China Lake designed and built a pair of small rocket motors that offset wind effects. A later redesign incorporated a larger, higher performance rocket motor that provided the necessary range while allowing lower trajectories, thus avoiding the high-wind conditions altogether.

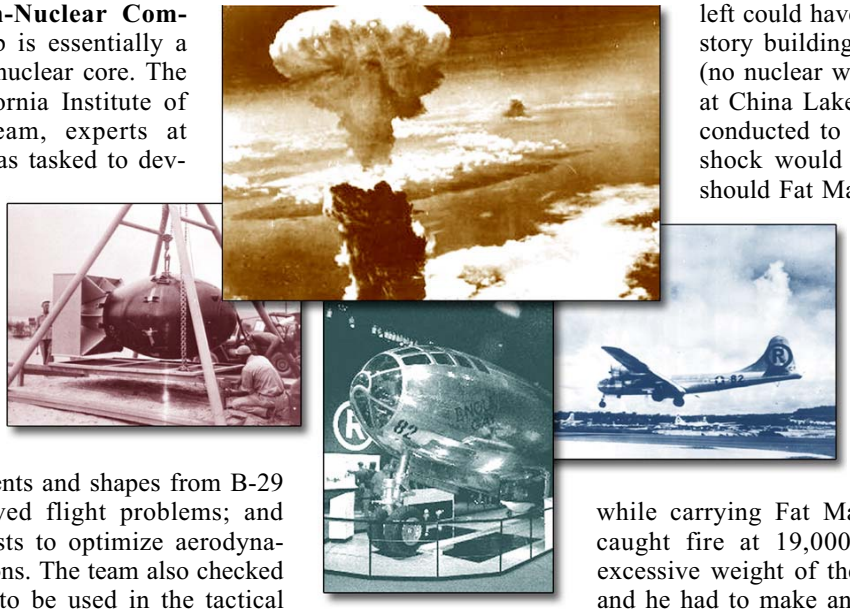
Vertical Launch ASROC (VLA). Advances in sonar technology in the early 1970s enabled ships to detect targets far beyond the range of ASROC. The Navy's response was VLA. In the 1960s, China Lake had already conducted the QuickTurn/Agile programs that demonstrated advanced TVC airframe controllability. By the mid 1970s China Lake efforts had resulted in vertical rail launches of both Chaparral and Sparrow missiles, followed by two vertical rail launches of modified ASROC airframes with TVC. In 1978 a major milestone was achieved at China Lake when the first vertically-launch-controlled ASROC airframe was launched from a prototype of the Mk 41 Vertical Launching System. Several years later the formal VLA Development Program was initiated, and VLA missiles were introduced into the Fleet in March 1993. China Lake was responsible for developing and testing the autopilot, staging system, rocket motor, and the TVC system for VLA. Goodyear Aerospace (now Lockheed Martin) was the prime contractor that productionized the WD design. The China Lake TVC technology provided the basis for numerous weapon-system advancements including the Mk 106 Tomahawk (jet tab TVC), the Mk 111 Tomahawk (ball-in-socket, moveable nozzle TVC), and the Mk 72 Standard Missile booster (ball-in-socket, moveable nozzle TVC). WD continues to support propulsion steering technology through the ongoing Compact Low-Cost Thrust Vector Control Program and is also engaged in programs using jet vane technology, including the Sidewinder AIM-9X missile and the Evolved SeaSparrow Missile (ESSM). TVC technology is also involved in the SM-3 Third Stage Rocket Motor, a key element in the Navy's Sea-Based Theater Ballistic Missile Defense Program.

ASROC in Conflict. During the **Middle East** and **Falklands** conflicts, China Lake demonstrated a new telemetry system for ASROC. During the **Vietnam** Conflict, ASROC entered the Fleet (1961) and replaced the Rocket-Assisted Torpedo. In 1958 the Mk 44 ASROC-launched torpedo was introduced. ASROC has been used by 253 U.S. and 69 foreign warships. U.S. Navy production ended in 1993, but the system is still being actively procured by allied foreign governments. VLA has replaced ASROC in the U.S. and among several Allies that also use the vertical launching system. [13]

Atomic Weapons

Fat Man and Little Boy. Of all the "weapons that win wars," the ones that can best lay claim to this title are the first atomic bombs, Fat Man and Little Boy, which helped to end World War II. China Lake was a major contributor to the success of those weapons. The U.S. initiated a program in 1942, under the Army Corps of Engineers, to build a weapon that would allow the U.S. to end the war without having to invade Japan. Several large engineering and production centers were set up at remote sites including sites in Tennessee, Washington (state), New Mexico, and California. In 1945, China Lake (then known as the Naval Ordnance Test Station or NOTS) carried out Project Camel, the code name for the Station's involvement in the Manhattan Project.

China Lake's Role: Non-Nuclear Components. An atomic bomb is essentially a conventional bomb with a nuclear core. The China Lake and the California Institute of Technology (Caltech) Team, experts at conventional explosives, was tasked to develop the non-nuclear explosive components of the atomic bomb; the conventional explosives were used to trigger the nuclear explosion. China Lake also performed detonator testing; mixed, melted, cast, and machined explosive shapes; air-dropped hundreds of bomb components and shapes from B-29 bombers; studied and solved flight problems; and conducted aero-ballistic tests to optimize aerodynamics and to test fuze functions. The team also checked out equipment procedures to be used in the tactical delivery of the atom bomb.



Hiroshima and Nagasaki

The Little Boy uranium-based atomic bomb was air dropped over Hiroshima, Japan, from the *Enola Gay* on August 6, 1945 and exploded with a force equivalent to 12,500 tons of TNT. On August 9, Fat Man, an implosion-type plutonium-based atomic bomb, destroyed Nagasaki with a blast equal to more than 20,000 tons of TNT. The bombings brought a swift end to one of the bloodiest wars in human history. China Lake developed and tested many of the non-nuclear components and the conventional explosives necessary for both types of bombs to work.

Research and Development. Two methods for nuclear fission were studied. One method involved a special gun to fire uranium. The second method involved an implosion method using plutonium. Both methods were used. The first problem was finding reliable detonators with incredibly fast action, a millionth of a second, and multiple detonations timed to within microseconds. China Lake loaded and test fired the new detonators made in Pasadena. China Lake, at its Salt Wells Pilot Plant, also cast and machined precision high-explosive lenses that focused blast waves to create the phenomenal heat and pressure required for the plutonium core to fission. The actual nuclear components of the bomb were developed at Los Alamos, New Mexico. No nuclear components were ever developed or tested at China Lake.

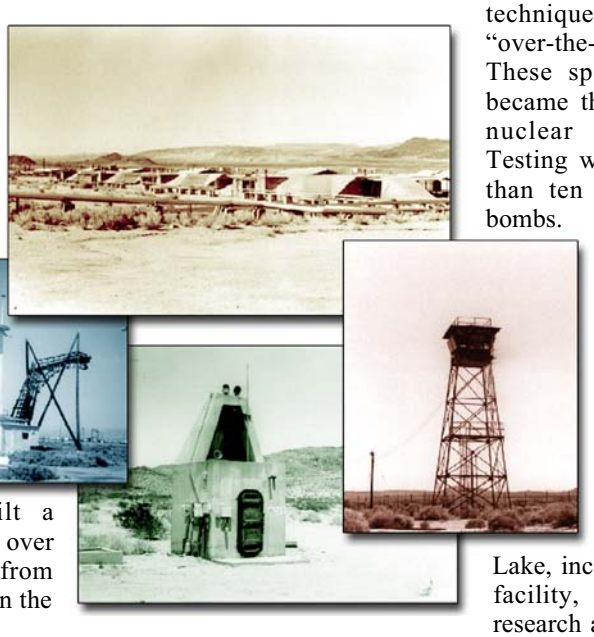
Testing. Aerodynamically, the early bomb configurations were incapable of accurate flight. Hundreds of drop tests with different fins and weight distributions were required to solve the problem. This work was conducted at China Lake and several other sites around the country. The first dummy bomb dropped at China Lake from 25,000 feet was buried so deeply that crews worked for days to recover it, and the hole that was left could have accommodated a ten-story building. Only dummy bombs (no nuclear warheads) were dropped at China Lake. Sea testing was also conducted to determine whether the shock would detonate the weapons should Fat Man or Little Boy be jettisoned at sea. Commander John T. "Chick" Hayward, NOTS experimental officer who went on to achieve the rank of vice admiral, flew 87 test flights in B-29s at China Lake. On one test flight, while carrying Fat Man, Hayward's engine caught fire at 19,000 feet because of the excessive weight of the 10,000-pound bomb, and he had to make an emergency landing at the North Island Naval Air Station.

Salt Wells Pilot Plant. The deadline for building at China Lake was set: less than four months in which to construct 80 buildings (52 permanent) and begin operations 100 days after groundbreaking. Challenges in building, equipping, and operating the facility were enormous. Engineers developed remotely controlled melting kettles and built specialized radiographic equipment to inspect the explosive blocks for fissures or cracks. A periscope-type optical system was devised that enabled a control-room operator to safely machine blocks of high explosives to close tolerances while separated from his work by two heavy concrete walls. All buildings were designed to hold a temperature tolerance of $\pm$ 2°F.

115 Days–243 Million Dollar Construction

In only 115 days, the $13,000,000 plant ($243 million in today's dollars) was melting, casting, and machining explosives for the Manhattan Project. Operations began just nine days after the test of the world's first nuclear weapon at Trinity Site, Socorro County, New Mexico.

Bomb Assembly. Materials and equipment shipped to China Lake for Project Camel were intentionally labeled with innocuous and misleading markings. This avoided drawing attention to the items during transport. One such label was "One Kit, Bomb Assembly." Each kit contained everything required to assemble an atomic bomb, including half a dozen Quonset huts and a pair of 40- by 40-foot steel buildings with air conditioners. Two kits (one a spare) were shipped to Tinian and Iwo Jima to assemble the Hiroshima and Nagasaki bombs. One kit was reportedly sent to Wendover Army Airfield in Utah as a reserve. The fourth was set up at NOTS, near Armitage Field. With that "kit," NOTS employees assembled multiple atomic bombs that were complete except for the nuclear core. China Lake also custom-built a specialized loading pit; the B-29 would drive over the pit, and the bomb would be uploaded from underneath. Duplicate loading pits were built on the islands of Iwo Jima and Tinian.



"Today, the whole world knows the secret which you have helped us keep for many months. The atomic bomb, which you have helped to develop with high devotion to patriotic duty, is the most devastating military weapon that any country has ever been able to turn against its enemy. No one of you has worked on the entire project or known the whole story. Each of you has done his own job and kept his own secret, and so today I speak for a grateful nation when I say congratulations and thank you all."

—Robert P. Patterson, Undersecretary of War

Salt Wells-Post War. In 1946, the Salt Wells Pilot Plant was ordered to step up production. Because Salt Wells was the single source for high-explosive components of the fission-type bomb, no other such facility had been built anywhere.

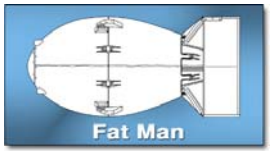
850 Workers at Peak Production

Through the mid 1950s, China Lake continued to be a major producer of certain chemical explosive components for the atomic weapons program. At the peak of its operation, the Plant had 550 employees plus 300 in support activities. China Lake efforts helped develop a DOD arsenal of dependable nuclear weapons and promoted the development of an industrial sector capable of producing nuclear-weapon components. Initial work at China Lake laid the groundwork for some of today's most advanced nuclear weapon systems.

Post-War Delivery Tactics. From 1951 to 1953, the Air Development Squadron FIVE (VX-5) at China Lake was charged with developing a delivery tactic that would get the nuclear weapon on or close to the target while providing an escape envelope for the aircraft and pilot. VX-5's personnel were top caliber; the average flight time per pilot was more than 2,000 hours. These officers and about 100 enlisted men worked tirelessly, testing and perfecting bomb-delivery techniques described as "loft/toss," "over-the-shoulder," and "lay-down." These specialized maneuvers soon became the Navy way of delivering nuclear weapons from aircraft. Testing was intense, including more than ten thousand Mk 76 practice bombs.

Historical Sites. Many of the original buildings used in the atomic-bomb work at China Lake are still standing and have been nominated to the National Register of Historic Places. These buildings include facilities at Salt Wells and mainsite China Lake, including the fuze construction facility, steam plant, inert-material research and development laboratory, and develop-process facility as well as the Camel test camera shelter, four drop-test buildings, the control tower, X-Pad, and Building X.

Fleet Special Weapons. China Lake developed delivery systems—but not warheads—for a variety of strategic and tactical nuclear weapons. China Lake developed an underwater-launch capability for nuclear missiles and conducted penetration and feasibility studies for nuclear weapons. In the early 1950s, China Lake redesigned the **Elsie** (TX 8/TX 11) nuclear-penetrator weapon and developed the Bombardment Aircraft Rocket (**BOAR**), one of the earliest rockets designed to carry a nuclear warhead. China Lake demonstrated a submarine-launched bombardment missile called **Marlin**, in 1957, and supported the antisubmarine nuclear-weapon system **SUBROC**. **Regulus**, an early submarine-launched nuclear cruise missile, came to Point Mugu for T&E in 1949 and became the largest single program in Point Mugu history, in terms of manpower and facilities. In the 1980s China Lake made contributions to fuzing and flight-termination systems of the **SM-2(N),** the nuclear version of Standard Missile, and developed the data link for **Seek-Bang**, the Air Force's nuclear Walleye program. The Manhattan Project work influenced the Fleet Ballistic Missile family, beginning with the Polaris missile and culminating with today's Trident II. [14]



FAE

Definition. Fuel air explosives (FAE) weapons use an explosive charge to disperse liquid fuel into the air, which creates an aerosol fuel/air cloud. When the cloud reaches an optimized mixture, it is ignited by a detonator, creating a shock wave front that is useful against soft targets such as minefields, personnel, aircraft in the open, and bunkers. FAE has also been used for creating clearings in forests and jungles.

WD Initial Role. Since 1960, China Lake has developed FAE weapons and devices, including two 550-pound weapons, the CBU-55 and CBU-72 cluster bombs, both containing three FAE submunitions loaded with ethylene oxide liquid fuel. An aerosol cloud about 45 feet in diameter and eight feet thick is created. The rapidly expanding shock wave front damages all objects near the center and produces substantial damage beyond the aerosol area.

Also developed at China Lake were the FAE II BLU-95/B (500 pounds) and the BLU-96/B (2,000 pounds). A surface-launched version, SLU-FAE, also developed by China Lake, was a system of rocket-propelled FAE warheads launched from a tracked vehicle to clear a safe lane through a mined area. Because FAE does not have long-range fatal fragments, it can be used in close proximity to friendly forces.

China Lake investigated an entire family of FAE weapons—from grenades to 2,000-pound bombs to surface-launch units. The family includes FAE I, SLU-FAE, Mass-Air-Delivery (MAD)-FAE, and Catapult-Launched (CAT)-FAE. R&D at China Lake includes improved FAE fuels, dispensers, fuzing, and initiation systems. The CBU-55A/B was developed for use with rotary-wing and slow-speed aircraft, and the CBU-72/B was developed for use with high- speed aircraft. The Navy and Marine Corps have successfully used both of these weapons.

FAE in Conflict. During **Desert Storm,** China Lake revived FAE to help the Marines, who dropped 254 CBU-72s, primarily from A-6Es, against minefields and personnel in trenches. In addition to real lethality, FAE was an effective psychological weapon because of its large shock wave footprint. Marines first used FAE in **Vietnam** combat, employing canisters of ethylene oxide for minefield clearance in 1967.

In the early 1970s the CBU-55/B was extensively used and became a standard weapon of naval aviation forces. Subsequently, the CBU-72 for fixed wing aircraft was developed for low-level delivery from high-speed aircraft, and this was also used in Vietnam. Hand-emplaced FAE canisters were used for clearing mines, and FAE devices were used to rapidly clear helicopter-landing zones in the jungle and to neutralize field fortifications.

WD Current Role. Liquid FAE weapons suffer from aging effects of the fuel, with early weapons limited to a shelf life of 10 years. Work was started in the early 1980s to find a replacement fuel. Efforts included gels and powered explosives, but these were not successful. However, attempts with metalized gels yielded a new phenomenon then called "Solid FAE." This led to further development—a material called metal-augmented-charge (MAC). MAC was introduced into the Hellfire weapon in 2003 and was used very effectively during the beginning hours of **Operation Iraqi Freedom**. [15]

Fleet Ballistic Missiles
Polaris, Poseidon, Trident

Definition. Fleet ballistic missiles are large, long-range, submarine-launched missiles equipped with nuclear warheads. Although never fired in combat during more than 40 years of service, Fleet ballistic missiles have played a central role in the U.S. policy of strategic deterrence.

WD Initial Role. Responding to a growing Soviet nuclear threat in the 1950s, the U.S. began developing intermediate-range ballistic missiles. The Navy realized that the original submarine-launched ballistic missile (SLBM) candidate, the Army Jupiter missile, was too large and heavy for shipboard use and the liquid fuel was too toxic. China Lake, working with the Bureau of Ordnance, developed the concept for Polaris: use a small solid-fueled rocket motor to launch the missile from a submarine. Analysis suggested a smaller warhead and a new reentry body concept. Feasibility studies, component tests, fuzing and rocket motor tests, and full-scale underwater-launching programs were conducted. In the early 1970s, the Navy was calling for new, larger submarines and longer-range missiles, and the Trident program was begun. In the late 1980s, Trident D5 flight-testing began.

China Lake Major Contributions

Work on Polaris, Poseidon, and Trident have advanced the state of the art in thrust-vector-control systems, propellant efficiency and safety, and large rocket-motor technology. Work has included basic research, engineering and advanced-development efforts, support for operational systems, and technical advice. China Lake's greatest efforts have been in propellant hazard evaluation and aging characterization, as well as testing and evaluating propulsion systems. The early China Lake studies had a profound effect in shaping the country's strategic deterrence policies, which contributed to international stability.

Polaris. The UGM-27 Polaris was a solid propellant, SLBM that had two stages of propulsion. Polaris A-1 weighed 28,800 lbs. and had a range of about 1,000 nautical miles. The Eisenhower administration accelerated Polaris deployment, and the first successful underwater launch of a Lockheed-built Polaris A-1 was from *USS George Washington* on July 20, 1960, off Cape Canaveral, Florida. The A-1 entered service in 1960, and the A-2 entered service in 1961 and was fitted on 13 submarines. By March 1961, President Kennedy announced plans for 29 Polaris submarines. In 1962, *USS Ethan Allen* launched a Polaris that flew 1,700 miles and detonated, America's only ICBM test with a live nuclear warhead. The A-3, weighing 35,000 pounds with a range of about 2,500 nautical miles, entered service in 1964. Conversion of the Polaris submarine fleet to Poseidon C3 missiles began in 1969, and by 1977 about 30 Polaris ballistic missile submarines had been converted. China Lake provided T&E support for Polaris throughout the life of the program.

China Lake's Pasadena Annex operations used San Clemente Island, with steep cliffs and deep, clear offshore waters, that offered ideal test conditions. The Polaris Pop-Up Facility was constructed on the ocean floor and included two concrete launching pads. Seven cliff-top spotting stations were equipped with range instrumentation. The first pop-up tests used redwood logs, rather than missiles, fired from an underwater launcher. The Hydroballistics Laboratory—one of only three such facilities in the world—was used to study flow characteristics. A special crane and cable were developed to reel in the test missiles. Each test was complicated, requiring a test crew of about 80. In April 1958, President Eisenhower, Secretary of the Navy Thomas Gates, Chief of Naval Operations Arleigh Burke, and other key decision-makers viewed a NOTS film showing the Pop-Up Facility. The presentation so impressed Burke that when he later toured NOTS, he asked to see the pop-up operation first-hand.

A propulsion research laboratory was built to investigate and monitor the combustion instability characteristics of strategic propellants. In addition, the need for a static-test facility led to the construction of the Skytop Static-Test Facility, which can horizontally test motors with thrusts to 1,000,000 pounds and vertical-test (nozzle down) motors with thrusts to 200,000 pounds. Skytop is the Navy's largest propulsion static-test installation.

Poseidon. In 1965, President Johnson announced another Polaris update, Poseidon, weighing in at 65,000 pounds. Poseidon could deliver a much larger payload with greater accuracy than the Polaris A-3 and was the first to carry a multiple independently targetable

reentry vehicle (MIRV) payload of up to 14 small reentry vehicles. Poseidon became operational in 1971, and eventually 486 missiles were operational on 31 Fleet submarines. In 1994, Poseidon boats were converted to carry the Trident C4. Poseidon's design and hardware were strongly influenced by China Lake studies, and the center tested Poseidon motors until 2003, when all C-3 Poseidon missiles were removed from service.

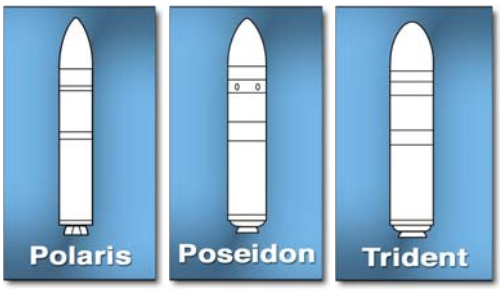
Trident. In the 1970s, the Nixon administration called for an Underwater Long Range Missile System that required a larger, more accurate missile—Trident I. In 1974 a development second-stage motor detonated during a test firing, and China Lake was selected to study the causes of the motor malfunctions and perform developmental motor firings. In support of that effort, the center participated in the Trident alternate-propellant program that led to new, more robust propellants; Strategic Systems Program also built the Radiographic Inspection Facility that housed a high-energy computer-aided tomography system, a "CAT scan" for rocket motors. Successful completion of these programs resulted in the UGM-96 Trident C-4, weighing 73,000 pounds with a range greater than 4,000 nautical miles, entered service in 1979. On Veterans Day, 1981, Vice President George Bush commissioned *USS Ohio*, the first Trident submarine.

In 1983, President Reagan moved ahead with plans for the larger, more accurate Trident II. The Trident II D-5 is a three-stage, solid propellant, inertially guided missile with a range of more than 4,000 nautical miles. After 15 of 18 successful land firings, the first underwater launch in 1989 experienced flight control failure and the missile was command destructed. China Lake was assigned to the task of failure analysis. Design improvements were made, and the missile has never malfunctioned since. Today, Trident is at the heart of America's nuclear arsenal and is expected to remain fitted to *Ohio*-class boats.

Trident in Conflict. Trident submarines are among the world's most lethal weapons, silently and invisibly prowling the oceans, powered with atomic energy, and armed with nuclear warheads. There are 18 Trident submarines each armed with 24 nuclear missiles, and each missile carries eight warheads aimed at different targets. These submarines are four stories tall, more than 580 feet long and travel almost 30 mph underwater. For more than 20 years, Trident has served as a quiet, invisible, and yet constant major nuclear deterrent—the backbone of America's strategic defense.

WD Current Role. China Lake evaluates the Trident propellant aging properties to help the Navy understand the quality and reliability of the Trident weapon inventory. WD also helped develop technology to contain and scrub the exhaust during motor destruction, emitting only carbon dioxide and water. This demilitarization technology was a first and resulted in the full-scale Modified Contained Burn Assessment Test Facility, which successfully demonstrated 98+% removal efficiencies on full-size, 20,000-pound motors, and ensured that the program could meet START requirements. China Lake is involved in the Trident D-5 Service Life Extension Program, which seeks to find alternative sources of supply and qualify new component production methods. China Lake is developing the test methods and evaluating the new materials. During 2000-2001 the Naval Weapons Test Squadron at Point Mugu modified P-3s to support DOD Trident operations from Kwajalein Atoll in the South Pacific, to Kodiak, Alaska, to Mauritius Island in the Indian Ocean. The China Lake propulsion test complex, Skytop, continues to support all rocket motor static test efforts—production evaluation tests, aging motors, life extension, and new technology demonstrators. Throughout the entire Fleet ballistic missile program, China Lake has tested more than 500 motors.

In November 2003, WD was given a Trident Command Flag by the Trident Missile Branch, Washington, D.C., during a ceremony commemorating the 20th anniversary of Trident I missile launches at Point Mugu. This is the second WD flag to be presented. The first flag was awarded to China Lake in 1993 for development support and static testing of the propulsion system. WD is also very active in the Trident II program. [16]



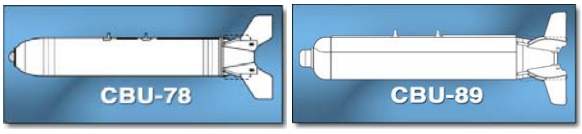
Gator

Definition. Gator is an aircraft delivered, unguided, target-actuated triservice anti-personnel and anti-tank munitions (land-mine) delivery system. It is used primarily against area targets such as tanks, armored vehicles, trucks, radar installations, surface-to-air-missile (SAM) sites, parked aircraft, and other materiel. The Air Force's CBU-89 Gator Mine is a 1,000-pound cluster munition. The Navy CBU-78/B is a 500-pound-class cluster weapon that uses the Mk 7 Rockeye dispenser. Rockeye has been in high-rate production for many years. Gator provides a means to emplace minefields on the ground rapidly, using high-speed tactical aircraft. Gator mines have a programmable self-destruct feature that permits the battlefield commander to control the timing of a counterattack or defensive maneuver.

WD Initial Role. The Gator system was originally developed by China Lake as part of the "eye" series of free-fall weapons. The free-fall weapon program was initiated at China Lake in 1959 to develop new free-fall bombs and systems that would improve the Navy's air-attack. Deneye was the precursor of the contemporary Gator system that dispenses terrain-denial mines. China Lake was the Navy's lead development laboratory and was responsible for technical management of the Gator kit to adapt Army-developed surface-scatterable land mines to Navy and Air Force air-launched dispensers. Gator is delivered with the Mk 7 (Rockeye) dispenser. It was released for production in 1982.

Gator in Conflict. During **Desert Storm**, China Lake increased Gator weapon delivery by a factor of four. Gator performed well in limiting the mobility of the Iraqi Army. During the Gulf War, the U.S. Air Force employed 1,105 CBU-89s. The CBU-78/B was used to hamper Iraqi movement in areas known to hide Scud launchers. During the **Iran/Iraq war**, the Gator scatterable land mine system was also used.

WD Current Role. WD is responsible for in-service engineering and logistics support. Portions of the inventory are being retrofitted with improved proximity fuze capability. [17]



General Purpose Bombs

Definition. The Mk 80 weapons are air-to-surface, free-fall, non-guided, general purpose (GP) bombs, including the 250-pound (Mk 81), 500-pound (Mk 82), 1,000-pound (Mk 83), and 2,000-pound (Mk 84) versions. The Mk 80 series was developed in the 1950s in response to the need for bombs possessing less aerodynamic drag, for operation on jet aircraft. Bombs are fitted with either a nose or tail fuze to meet specific tactical needs such as fragmentation, blast, cratering, or penetration. They can also be used for land or sea mines. Later versions including the Mk 82/83/ 84 can be modified with a high drag tail assembly for low-altitude delivery.

WD Initial Role. China Lake and Point Mugu have been actively involved with RDT&E of bombs since WWII. During the 1940s, China Lake developed accurate bomb directors (Mk 6, Mk 10, EX-1) for single-seat aircraft, and fire-control systems (Mk 8, Mk 16, EX-16). In the early 1960s China Lake became the Navy's Lead Laboratory for free-fall weapons and developed the "Eye" series of weapons, including Rockeye I (cluster bomb), Rockeye II (antitank cluster bomb), Briteye (balloon-borne flare), Deneye (mine-dispenser), Fireye (gelled-fuel), Gladeye (multioption dispenser), Snakeye (fin retarded bomb), and Sadeye (cluster bomb dispenser).

Rockeye II can penetrate 7.5 inches of armor. It was fielded in 1968 and proved very effective in Vietnam/Southeast Asia against trucks, convoys, anti-aircraft sites, parked aircraft, radar installations, and personnel. During **Operation Desert Storm**, U.S. Marines used the weapon extensively, dropping 15,828 of them against armor, artillery, and antipersonnel targets. The Air Force dropped 12,159 bombs.

China Lake also produced the antipersonnel/antimateriel (APAM) cluster weapon as well as the Gator air-delivered mine system, which employed the Rockeye dispenser. When delivering weapons at low-altitude there was a need to slow the bomb down to allow the aircraft to escape the blast pattern. China Lake was actively involved in the development of an air-inflated retarder, or AIR device (a combination balloon and parachute) to accomplish the task. In addition, China Lake developed the first high-drag bomb, Snakeye, which incorporated folded fins on the rear of the bomb that popped open at release to increase the drag on the weapon. Snakeye was fielded in 1964 and has been used extensively since.

Today, WD is a leader in developing insensitive munitions (IM), making bombs safer to store and transport. WD has improved the IM capability for a family of bombs that includes the guided bomb unit (GBU)-24 and BLU-110 and -111 general purpose bombs. WD qualifies contractors that manufacture a wide range of bombs.

The Weapons Division has also implemented a best-value acquisition process for procuring the Mk 80 series, which saves millions of dollars each year. WD is currently improving technology for bombs and bomb components through new paints, "coiled cord" fuze cables, the FZU-61 lanyard, FMU-139 fuzes, and leaflet delivery systems. During **Operation Iraqi Freedom**, WD Fleet Weapon Support Team assisted forward-deployed personnel with the PDU5B leaflet bomb. During psychological operations, more than 31,800,000 leaflets were dropped.

Engineers at the Weapons Division have caused a minor revolution in how bombs are designed and fabricated. China Lake used cast iron (ASTM A536 Grade 60-40-18 cast ductile iron (CDI)) for new high-tech bombs. Traditionally, general purpose bomb bodies are made of forged steel, but fabrication is expensive, time consuming, and there are few producers. New casting techniques have eliminated the expensive processes of forming, welding, and heat treatment and the process has also eliminated the need for concrete fill in practice bombs. In addition, the CDI practice-bomb bodies are rebuildable and reusable. China Lake designed, developed,

and tested the BDU-50 C/B 500-pound practice bomb for the Air Force. Competitive production was conducted in 2003. Engineers are now working on live-load CDI bomb bodies as well, and work proceeds on the Air Force Mk 82 500-pound bomb and Mk 84 2,000-pound bomb.

General Purpose Bombs in Conflict. During **Operation Iraqi Freedom**, 9,251 unguided munitions were dropped, including the Mk 82 (5,504), Mk 83 (1,692), Mk 84 (6), Cluster Bomb Unit (CBU)-87 (118), and CBU-99 (182). During **Operation Enduring Freedom**, 10,870 bombs were dropped, including Mk 82 (6,344), Mk 83 (195), Mk 84 (4,167) and CBU-87 (164). WD conducted Forward Air Controller (FAC) training involving Mk 76 practice bombs. During **Kosovo**, more than 1,100 CBUs were dropped. Each carried an average of 202 bomblets. During **Desert Fox**, more than 600 bombs were dropped. And during **Desert Shield/Storm**, an estimated 24-30 million bomblets were dropped. Bombs were used against artillery, trucks, bunkers, scuds, surface-to-air missile sites, antiaircraft artillery sites, early warning radars, supply points, and troops. More than 12,000 Mk 84s were expended during Desert Storm, mostly by the Air Force. More than 200,000 unguided "dumb" munitions were used and more than 9,000 laser guided munitions. During **Vietnam** the China Lake-developed Bullpup B, with a 1,000-pound warhead, saw action as well as the Rockeye I and II 500-pound cluster bombs. Snakeye was released for production in 1964. The retarding tail assembly Mk 15 was introduced to the Fleet in 1970 and was used extensively in Southeast Asia. China Lake also developed and applied FAE technology to devices ranging from grenades up to 2,000-pound FAEII bombs.

WD Current Role. WD continues to support the production and delivery of the general purpose bombs to the Navy and Air Force weapon inventories. In this role, WD engineers work closely with the weapon contractors and have improved acquisition efficiencies to enhance deliveries and product quality. [18]

HARM

Definition. The High-Speed Antiradiation Missile (HARM) is an air-to-surface guided missile used to seek out and destroy enemy radar systems.

WD Initial Role. HARM was conceived at China Lake and became a joint Navy-Air Force project. China Lake pioneered anti-radar (passive RF) guidance for the Shrike missile, which evolved into HARM to meet Fleet needs for a wide-frequency coverage high-speed anti-radiation missile. The basic overall design, including seeker, warhead, and fuze were developed at China Lake, which also developed a procurement package for a second-source competition. China Lake, as Lead Laboratory, provided technical management to prove the concept and to establish feasible performance specifications. China Lake designed and fired nine programmed test missiles and three guided missiles before contracting with industry. First production deliveries occurred in 1983 and the weapon has steadily evolved as our understanding of the threat has evolved.

In the late 1990s, WD launched seven HARMs simultaneously during a Fleet Battle Exercise Echo. During 2001, WD supported the international HARM upgrade program, including system engineering and developmental and aircraft integration testing. WD performed systems engineering to integrate the AARGM seeker, developed new Operational Flight Programs, and released new software. WD also conducts HARM University for Navy, Marine, and Air Force aircrews, an intensive four-day training course (21 classes). In addition, during the Fall of 2002, the Italian Air Force tested HARM on China Lake ranges for three months. In a first-time-ever maneuver, WD fired two HARMs sequentially from an F/A-18 Super Hornet at separate targets. Both hit right on target.

HARM in Conflict. During **Operation Iraqi Freedom**, 408 AGM-88 HARMs were fired. On the first night of major air operations, HARMs were used to strike command centers and achieve rapid dominance over Iraqi air defense operators, who were successfully deterred from operating radar for the rest of the conflict. WD assisted in foreign material exploitation (FME) flight tests supporting the National Security Agency.

In addition, the EA-6Bs escorted strike groups while performing jamming and employing HARM against hostile radars. Point Mugu responded to more than 100 Fleet requests concerning EW warfare data, and generated new theater electronic-intelligence (ELINT) files, to enable HARMs to engage and defeat emerging or new threat radars, three months ahead of schedule for the EA-6B and F/A-18. During **Northern** and **Southern Watch,** WD answered an urgent request for HARM training aboard *USS Roosevelt*. A WD team deployed in theater and provided missile updates and initial operator training aboard *USS George Washington*. During **Kosovo**, and **Operation Allied Force**, Navy, Air Force, and allied aircraft fired more than 1,000 HARMs, and a Tiger Team from WD was deployed to Italy in support of forward-deployed forces. The team verified the ready-for-issue (RFI) condition of more than 400 missiles in 36 days.

In **Operation Desert Storm**, more than 2,000 HARMs were fired. Mastery of electronic warfare helped U.S. aircraft make thousands of bombing runs over Iraq with remarkably few causalities. Point Mugu adapted the EA-6B to the new Block III and IV HARMs to counter Iraqi radar. China Lake deployed a field team in theater to update missile and aircraft avionics software and provide training. HARM also proved effective against Libyan targets in the **Gulf of Sidra** in 1986.

WD Current Role. WD provides Fleet support with HARM University, Tactical Manual (TACMAN) development, and ARM Steering committees; development and test of new ELINT files to enable HARM against new threats; and Command Launch Computer software; TAMPS MPM and JMPS UPC development; FME; and International HARM Upgrades. Raytheon serves as the prime contractor. [19]

Harpoon, SLAM, SLAM-ER

Definition. The AGM/RGM/UGM-84 Harpoon is an autonomous, all-weather, over-the-horizon, antiship missile system providing the Navy and Air Force with a common missile for air, ship, and submarine launches. Developed in the early 1970s, Harpoon is one of the most widely exported Navy weapon systems, with more than 30 nations fielding the system. In the late 1970s, an air-launched version was deployed on the Navy's P-3 Orion and a surface-launched version was deployed aboard Navy destroyers. The AGM-84D was later adapted for Air Force bombers. Harpoon is a "fire-and-forget" missile system, using both inertial and active-radar guidance. The blast warhead is effective against a wide variety of targets, including ships at sea and in port, coastal defense sites, SAM sites, exposed aircraft, and port/industrial facilities. The Block II upgrade incorporates elements of the Joint Direct Attack Munition and the Standoff Land-Attack Missile—Expanded Response (SLAM-ER) and uses GPS-aided inertial navigation to hit a designated aimpoint.

AGM-84E SLAM (Standoff Land-Attack Missile). In the late 1980s, the Navy needed a land-attack missile. Rather than design one from scratch, the Navy took everything from Harpoon except the guidance and seeker sections, added a GPS receiver, a Walleye optical guidance system, and a Maverick data-link to create SLAM. SLAM is an intermediate-range system, effective against high-value land targets and ships in port. The first missile was delivered in November 1988, was test fired from a *Ticonderoga*-class cruiser at Point Mugu, and entered service in June 1990. Automated mission planning for SLAM was introduced to the Fleet in 1996, and the last-production SLAM was delivered to the U.S. Navy in November 1997.

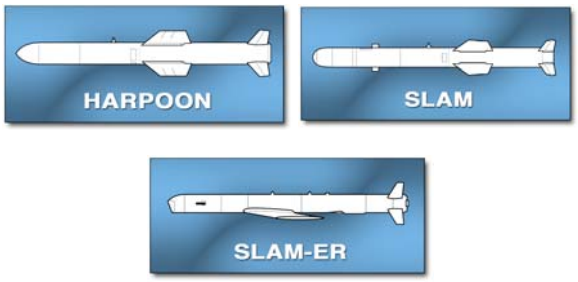
SLAM-ER (SLAM Expanded Response). SLAM-ER is a significant improvement over SLAM. It is a day/night, adverse-weather, over-the-horizon, precision strike missile addressing the Navy's requirements for a precision-guided Standoff Outside of Area Defense weapon. It can be launched from safe standoff ranges more than 150 nautical miles. In 1994 McDonnell Douglas, now Boeing, was awarded a contract for improving the range and aerodynamic performance, warhead lethality, and software. WD played a key role in developing a new warhead to improve the target penetration, accuracy, and lethality as well as meeting new insensitive munition safety requirements. The titanium warhead case contains a WD developed explosive that has excellent energetic and insensitive munition properties. The U.S. Navy successfully launched the first SLAM-ER from an F/A-18 Hornet in 1997. In 2001, the Navy launched a SLAM-ER Automatic Target Acquisition (ATA) missile on the test ranges at China Lake. The ATA pattern-matching algorithms compare the on-board reference image generated during the mission to the missile's infrared seeker image and automatically locate the preplanned aimpoint in the target scene. SLAM-ER, with ATA, became operational in September 2002.

WD Initial Role. In 1965 the U.S. Navy began studies for an antiship missile. In 1971 McDonnell Douglas was awarded the contract to develop Harpoon, and China Lake was designated as lead field activity providing technical production, and logistics support. China Lake also developed and improved the warhead. Working with industry, China Lake also developed and improved the fuze and the safety and arming device. In 1976 China Lake led a major quick-response effort to remedy a series of program quality and producibility problems. Successful completion of the Harpoon operational evaluation and Fleet introduction followed.

In 2000 and 2001 WD supported Harpoon Block II improvements, and Point Mugu demonstrated Block II upgrades on the Sea Range using the Mobile Ship Target (MST). Three successful live launches by the Air Force led to the integration of Harpoon on 30 B-52Gs. WD also integrated software on test aircraft for the United Kingdom and conducted Harpoon seeker littoral testing for the U.K. WD supported SLAM-ER integration on the S-3B, supported developmental and operational testing, developed, acquired and loaded government-furnished equipment (GFE) warheads and fuze boosters, developed new all-up-round software, and provided system engineering. The WD team wrote the systems specification and statement of work for the initial concept of SLAM. WD was involved in all engineering efforts from conception through full-rate production of the SLAM and SLAM-ER missile.

WD/Harpoon/SLAM in Conflict. During **Operation Iraqi Freedom**, five SLAM-ERs were fired. In **Operation Enduring Freedom**, four were used. A few weeks after 09/11/01, WD loaded upgraded software into several SLAM-ERs that were deployed aboard *USS John C. Stennis.* In 2000, three SLAM-ERs were fired in Iraq. During **Kosovo**, the Fleet Weapons Support Team supported P-3 deployment of SLAM and SLAM-ER. In Sigonella, Sicily, WD supported VP-10 with SLAM mission-planning equipment. In **Desert Fox**, WD continued developmental testing. In **Desert Storm** Harpoon was used by the Royal Saudi Navy to sink an Iraqi minelayer, and SLAM was first used in combat: seven air-launched SLAMs were used against high-priority Iraqi targets. In April 1988, four air- and surface-launched Harpoons sank an Iranian frigate and a fast-attack craft. In March 1986, five Harpoons were fired from aircraft and by the cruiser *USS Yorktown*, sinking two Libyan vessels and severely damaging several others. Harpoon was first used in combat in 1984 against Libyan missile ships in the **Gulf of Sidra**. During **Vietnam**, China Lake improved the insensitive-munitions capability of Harpoon, and Point Mugu developed the Cast Glance high-altitude-photography capability to support Harpoon tests.

WD Current Role. Although the U.S. Navy orders ceased in 1992, Harpoon upgrades are planned to continue to 2015. WD has a role in the development and engineering, T&E support, software integration, and Fleet logistics for Harpoon, SLAM, and SLAM-ER. The Boeing Company is the Harpoon and SLAM-ER contractor. WD works with industry to ensure quality of the warhead/fuze package. WD maintains a low-volume production capability as a backup to industry. This capability was used to ensure warhead deliveries when the industrial producer required requalification. [20]



Hellfire

Definition. The helicopter launched AGM-114 Hellfire missile is an air-to-ground missile that provides heavy antiarmor capability to attack helicopters. The first three generations of Hellfire use a laser seeker. The fourth generation, Longbow Hellfire, uses a radar frequency seeker. The first generation Hellfire was the main armament of the Army's AH-64 Apache. The second and third generations of Hellfire, the AGM-114B/K, are the main armament of the Marine Corps' AH-1W Super Cobra. Laser Hellfire homes on a laser spot that can be projected from ground forces, other aircraft, or the launch aircraft itself, enabling the system to be used in a variety of modes. Hellfire is effective against armored vehicles, and concrete bunkers.

WD Initial Role. Army Hellfire studies began in 1971 and advanced development continued through 1976, when an Army production contract was awarded. The first guided launch of an AGM-114 took place from an AH-1G Cobra helicopter in late 1978. Hellfire entered service in 1985 and was first used in combat by the Army in 1989 during **Operation Just Cause** in Panama. In 1985 Hellfire AGM-114B with a single shape charge warhead was approved for Marine Corps AH-1 helicopters. It was first fielded on the AH-1 Super Cobra in 1986. In 1995 Hellfire II AGM-114K with dual shaped charge warheads was fielded on Marine AH-1W helicopters and in 1998 on the Navy's SH-60B Seahawk helicopters. The current Hellfire version—AGM-114 Hellfire II—has expanded its original antiarmor target set to include close-air support, urban assault, and antiship missions. Three warhead types are available: shape charge, blast fragmentation, and enhanced blast fragmentation. During 2000-2001, WD provided systems engineering support and testing. Tests included developmental, insensitive munitions, safety and safe-separation, flight, and warhead performance. WD also investigated fixed-wing requirements, used advanced simulations to study proposed concepts, and provided survivability assessments and personnel training. WD established a Laser Evaluator System (LES) on San Nicolas Island to support the Armed Helicopter.

New MAC Warhead. In support of **Operation Iraqi Freedom**, WD designed, developed, and built a new metal-augmented-charge (MAC) warhead. The effects are formidable.

> "[The Hellfire] can take out the first floor of a building without damaging the floors above, and is capable of reaching around corners, into niches, and behind walls to strike enemy forces hiding in caves, bunkers, and hardened multi-room complexes. It went from development to deployment in less than a year."
>
> —Donald Rumsfeld, Secretary of Defense

The MAC warhead technology has its roots at China Lake where, as early as the 1960s, Navy scientists were conducting research into Fuel Air Explosives (FAEs). These concepts were turned into tactical weapons: surface-launched FAE (SLU-FAE) and the CBU-55/72 FAE family. In the 1980s, China Lake developed nonliquid FAEs containing aluminum particles. The goal was a solid FAE with a greater impulse (pressure over time) than conventional explosives. The work received a classified U.S. Patent and was the basis for the MAC warhead. Unlike conventional warheads that have a sharp pressure spike that decays rapidly, the MAC has a sustained pressure wave. "Thirteen months from funding to fielding," noted the project's systems engineer. "That was total design, development, assembly, explosive loading, integration into the missile armament section, and testing. Normally, that would be about a three-year project."

Hellfire in Conflict. During **Operation Iraqi Freedom**, 653 AGM-114 Hellfire missiles were used. In response to an urgent request by the sponsor of the MAC warhead, WD manufactured 60 MAC warheads for field use. In February 2001, an Air Force Predator UAV (unmanned aerial vehicle) fired an AGM-114C against a ground target during an air combat demonstration. This groundbreaking test proved the Predator's ability to operate as a tank killer with the ability to self-designate its Hellfire missiles. During **Operation Enduring Freedom,** WD and its tenant squadron, VX-9, accelerated range testing and activities as part of a Quick Reaction Assessment (QRA). WD also performed weapon effectiveness analysis and made advancements using the Quick Bolt Advanced Concept Technology Demonstration to modernize Hellfire. During **Operation Desert Storm**, approximately 1,600 Hellfire missiles were fired against Iraqi forces.

WD Current Role. WD supports all Navy/Marine Corps Hellfire variants from cradle to grave, conducts insensitive munitions (IM) and safety tests, assists with initial operating capability, and IM Waiver requests. China Lake's Tactical Weapons Office serves as Assistant Program Manager for Systems and Engineering and Class Desk for NAVAIR's Defense Suppression Systems Office. Point Mugu serves as Assistant Program Manager for Logistics and as the Fleet Support Team for integrated logistics support services of the Hellfire weapon system. Lockheed Martin is the prime contractor for Hellfire II. [21]

JDAM

Definition. The Joint Direct Attack Munition (JDAM) is a low-cost, inertial guidance kit that is attached to an unguided free-fall bomb, converting it to an accurately guided "smart" weapon. This strap-on global positioning system (GPS)/ inertial navigation system (INS) guidance kit improves the accuracy of general-purpose bombs. JDAM was developed to meet the need for an adverse-weather, accurate-strike capability in response to lessons learned during Desert Storm. JDAM is upgrading the existing inventory of Mk 82 500-pound, Mk 83 1,000-pound, and Mk 84 2,000-pound general-purpose unitary bombs and the BLU-109 2,000-pound hard-target penetrator bomb. The JDAM-equipped Mk 80 series bombs were assigned new guided bomb unit (GBU) designations.

WD Initial Role. In the late 1980s, the joint U.S. Navy-U.S. Air Force Advanced Bomb Family Program studied inexpensive ways to deliver conventional bombs more accurately. In the early 1990s, three major programs evolved: JDAM, the Joint Stand-Off Weapon (JSOW), and the Joint Air-to-Surface Standoff Missile (JASSM). WD has been integrally involved in all three programs and was designated the Navy Lead Field Activity for JDAM. Low-rate initial production of JDAM started in early 1997. WD began JDAM developmental testing on the F/A-18C/D in 1995, and on F/A-18E/F and F-14B in January 2000, on F-14D in January 2001, and on AV-8B in April 2001. JDAM achieved initial operational capability in April 2001, in time to see action in October 2001. In **Operation Iraqi Freedom**, WD accelerated hardware and software efforts as well as testing, and training and the Navy's F-14D Fleet became Mk 84 JDAM capable. In the late 1990s, WD demonstrated the Direct Attack Munition Affordable Seeker (DAMASK) concept, which sought to improve JDAM's 10-meter accuracy to 3-meter circular error probability (CEP).

JDAM in Conflict. During **Operation Iraqi Freedom** 6,542 JDAMs were dropped. When ground sources relayed the tip that Sadaam Hussein and his sons might be in a building, the coordinates were sent to a B-1B bomber already airborne. The B-1B hit the target with four GPS-guided JDAMs. Less than 12 minutes from the time the decision was made to attack, the bombs had struck. In **Operation Enduring Freedom**, Air Force and Navy aircraft dropped more than 7,000 GBU-31 and 1,000-pound GBU-32 JDAMs on Taliban Al-Queda targets in Afghanistan. WD provided JDAM capability to Fleet F-14B squadrons and conducted aircraft modifications and software loading on *USS Theodore Roosevelt*. WD provided Fleet training on JDAM fuzing reliability and conducted warfare analysis integrating JDAM on the F/A-18. During **Kosovo**, JDAM saw its first tactical deployment. WD completed software suite improvements and a successful support mission in Hungary, providing JDAM capability to Marine F/A-18s of Marine Air Group (MAG)-31. WD provided training, technical manuals, tailkits, and fuzes to operational forces. JDAM was a crucial weapon because of its ability to operate in bad weather. During Kosovo operations, at least 50% cloud cover existed for more than 70% of the time. JDAMs, delivered by B-2s, were still in low-rate production but were employed at nearly the same rate that they were being manufactured. And 45 B-2 sorties delivered 656 JDAMs on critical targets in the Federal Republic of Yugoslavia. The Air Force reported that JDAMs hit 89% of their targets. During **Kosovo**, WD provided urgent F/A-18 software upgrades, supporting Marine squadrons in the Balkans. During **Operation Desert Fox**, the Advanced Weapons Laboratory conducted the first F/A-18 mixed-weapons load using both JDAMs and JSOWs.

WD Current Role. JDAM is a joint Air Force/Navy weapon system. The Air Force serves as the lead, and WD serves as the Navy's technical agent for JDAM. WD provides Fleet technical support as well as support for contractor testing, mission planning and development, and logistics. JDAM is being produced by Boeing Missiles and Space Corporation. WD continues its role as Navy Lead Field Activity, providing continued support of JDAM/AV-8B integration activities and development support for a 500-pound version of JDAM. Currently, the Navy is planning a development effort to improve the accuracy of the JDAM by adding a strap-on infrared seeker that will reduce CEP to three meters. This is being accomplished as a part of the Hornet Autonomous Reactive Targeting (HART) Program, which provides an autonomous reactive-targeting capability with INS/GPS weapons on the F/A-18. [22]

JSOW

Definition. The Joint Stand-Off Weapon (JSOW) is an air-to-surface, unpowered, guided glide weapon. JSOW is a launch-and-leave weapon that uses GPS/INS and is capable of day/night and adverse weather operations. Aircrews have the ability to attack multiple targets in a single sortie. JSOW is delivered in three variants: baseline, antiarmor, and unitary (penetrator). The baseline JSOW uses hundreds of small bomblets to defeat multiple targets in one payload. The antiarmor JSOW uses six submunitions, each of which releases four projectiles (24 weapons) that use infrared sensors to detect targets. The unitary variant uses an imaging infrared terminal seeker to achieve point target accuracy with a 500-pound warhead.

WD Initial Role. In the late 1980s, China Lake served as the Lead Field Activity for the Advanced Interdiction Weapon System. In 1992 when the Air Force joined the program, the weapon's name was changed to JSOW. Under the Navy's new plan to reduce the number of weapon types, JSOW served as a partial replacement for six existing China Lake weapon systems: Maverick, Skipper, Walleye, Rockeye, APAM, and laser- and TV-guided bombs. China Lake played a significant role in the successful delivery of the first JSOW, overseeing development and preparing the Fleet for its introduction. The first flight test took place in December 1994 from an F/A-18C Hornet at China Lake. In December 1995, the Navy and Texas Instruments completed Development Test IIB at WD for the AGM-154A BLU-97 dispenser variant. JSOW test articles were deployed in 1997 aboard *USS Nimitz* and later on *USS Eisenhower*. Carrier Air Wing 9 deployed with five experimental JSOWs in fall 1997. In 1998, WD's Advanced Weapons Laboratory conducted the first F/A-18 mixed-weapons-load mission with JDAM and JSOW stores.

During 2000 and 2001, WD conducted the first live-fire JSOW tests on the B-2 and B-52, replaced defective rails, and instituted low-cost control section upgrades. Aircrews say they like JSOW because of its large standoff distance permitting launch well outside the range of most threat air defenses. A Navy/Raytheon JSOW variant, JSOW-154C, flew 32 miles and hit its target with precision accuracy in a WD-conducted test on the Land Range. Including this flight, JSOW-154C has since flown a total of three free flights, all exhibiting similar performance.

JSOW in Conflict. In **Operation Iraqi Freedom**, more than 300 AGM-154 JSOWs were launched. WD assisted forward-deployed forces with airborne-weapons bulletins concerning software configurations. During **Operation Enduring Freedom**, WD conducted JSOW tactical refinements and upgrades, and range testing and training were accelerated. JSOW and JDAM Common Munitions Built-In-Test Reprogramming Equipment (CMBRE) sets were provided to seven Navy carriers. Also during **Operation Enduring Freedom**, the WD F/A-18 AWL provided a major software block upgrade, the 15C SCS, incorporating more than 100 requirements to weapons, including JSOW. In addition, WD conducted developmental tests for JSOW B-52 integration with multiple-launch capability. The Navy's first F/A-18E Super Hornet deployed with JSOW, and program managers praised its performance and flexibility—45% of the 87 AGM-154A JSOWs used in **Operation Southern Watch** over Iraq were retargeted with new target coordinates in flight by the pilot and JSOW's GPS/INS were tested at WD's Integrated Battlespace Arena. During **Kosovo**, 11 JSOWs were launched, and WD provided JSOW training and technical support to *USS Kitty Hawk*, *USS Theodore Roosevelt*, and *USS Carl Vinson*. WD also provided systems engineering, flight test planning and training support, developmental and operational testing, logistics, and Fleet introduction. WD helped transport JSOWs from the U.S. to the Persian Gulf on less than 10 days notice. During **Operation Enduring Freedom**, **Allied Force**, and **Southern Watch**, approximately 100 JSOWs were employed. During **Desert Fox**, WD provided rapid response to Carrier Air Groups that requested some of the first production JSOW AGM-154A assets. The WD JSOW team rapidly identified requirements and reprogrammed weapons, addressing many logistical, software, and security challenges. JSOW was first employed in combat, by *USS Carl Vinson*'s air wing during combat in southern Iraq on January 25, 1999, as part of **Operation Southern Watch**. F/A-18 Hornets launched three JSOWs at three separate Iraqi surface-to-air sites, destroying all three.

WD Current Role. JSOW is a joint Navy-Air Force weapon program, with the Navy as the lead service. WD is the Navy's Technical Agent for joint development. WD provides systems engineering support for all JSOW variants; provides flight test planning, support, and execution for developmental testing and operational testing; provides logistics and training support; and conducts Fleet introduction and interface. Raytheon is the prime contractor. [23]

Laser Guided Bombs

Definition. Laser guided bombs (LGBs) are air-to-surface general-purpose bombs modified with laser-guidance kits. LGBs are used for precision attacks on surface targets. An airborne or surface designator illuminates or "tags" the target with a laser, and the weapon homes in on the reflected laser energy. LGBs are excellent performers in dive deliveries from medium altitudes. Variations include the 500-pound (GBU-12 Paveway II) and 2,000-pound (GBU-10 Paveway II, GBU-24 Paveway III, and GBU-15) LGBs.

WD Initial Role. During **Vietnam**, China Lake assisted the Air Force with a quick-reaction program to adapt their Pave Knife laser target-designator pod to the Navy's A-6 aircraft. Pave Knife was a potent weapon system. Attack squadron VA-145 destroyed 14 North Vietnamese bridges in three hours. In 1980, China Lake began developing a rocket-boosted version of the Paveway II GBU-16. The program was designated AGM-123 Skipper and entered Navy service in 1985. During **Operation Enduring Freedom**, WD Fleet Weapon Support Teams introduced GBU-24 weapon systems to the Fleet, and GBU-24D/Bs were rushed into theater.

Laser Guided Bombs in Conflict. During **Operation Iraqi Freedom** 8,618 laser guided bombs were used, including GBU-10 (236), -12 (7,114), -16 (1,233), -24 (23), -27 (11), and –28 (1). Because of their precision, LGBs have been the weapon of choice when extreme accuracy is required, such as against bridges or military targets in downtown Baghdad. During **Operation Enduring Freedom**, 1,330 laser guided bombs were used, including GBU-10 (13), -12 (1,003), -16 (274), -24 (34), –28(6). WD conducted more than 60 flight tests, dropping 500-pound LGBs. Using minimal-impact laser-guided training rounds (LGTRs) against tunnel targets at China Lake, WD advanced the capability of targeting tunnels with the existing Fleet targeting systems. During **Kosovo**, the majority of direct attack weapons were laser-guided bombs. During **Desert Storm** the F-111F and F-117 delivered the majority of the guided bombs. It was reported in 1992 that the Air Force had used 8,400 LGBs. In 1982, during the **Falklands** conflict, RAF Harriers dropped Paveway IIs. Approximately 9,300 laser guided bombs were dropped. During **Vietnam**, the Paveway I, the first LGB, entered service with the Air Force and was used in combat. Laser guided technology has greatly enhanced the effectiveness of general purpose bombs. For example, in WWII it would take thousands of bombs to hit a target the size of an aircraft shelter. In Vietnam, 300. Today, it can be done with one laser guided bomb.

WD Current Role. Point Mugu and China Lake continue RDT&E work on LGB systems. For example, WD has full cradle-to-grave responsibility for the 2000-pound Hard Target Penetrator GBU-24E/B. WD completed the extensive developmental test program and successfully demonstrated readiness for operational test in 2003.

When the military required a hard-target deep penetrating bomb, China Lake designed airframe enhancements to meet the Navy's catapult launches and arrested landings requirements. In addition, engineers qualified the BLU-116A/B design for use on the F/A-18 and F-14, and is currently providing production bombs to the Fleet. The BLU-116A/B, using the FMU-159A/B Hard Target Smart Fuze, or an FMU-143 fuze with time delay, can penetrate more than 10 feet of reinforced concrete with the bomb remaining intact, then detonate when it receives the fire pulse from the fuze. Initial Operational Capability is planned for 2004.

WD continues its role as the Navy production and in-service engineering agent for Laser Guided Bombs. WD maintains contact with the Air Force (executive service for LGBs) and Fleet users to maintain the interoperability of the LGB Guidance Kits. [24]

Maverick

Definition. Maverick is an air-to-surface tactical missile designed for close air support, interdiction, and defense suppression. It provides stand-off capability and high probability of kill against a wide variety of tactical targets, including air defenses, ships, ground transportation, armor, and fuel storage facilities. Guidance systems used by Maverick include infrared, laser and TV. The AGM-65 has two types of warheads, a 125-pound shaped charge with a contact fuze, a 300-pound penetrating blast heavyweight warhead with a cockpit selectable delay fuze that penetrates the target before detonation. The latter is very effective against large, hard targets. The propulsion system is a boost/sustain solid rocket motor. The pilot can engage several targets on one mission, and the missile has a "launch-and-leave" capability. Mavericks can be launched from high altitudes to tree-top level and can hit targets at ranges up to 17 nautical miles. The AGM-65E Laser Maverick, and AGM-65F Infrared Maverick, used by the Navy and USMC, has a 300-pound penetrating warhead. Maverick is exported to more than 25 countries.

WD Initial Role. Maverick was originally developed for the Air Force beginning in the mid-1960s, and the first deliveries were made in 1972. Subsequently, China Lake became heavily involved in modifications and refinements to the system. China Lake provided technical assistance to the Air Force, helped integrate the weapon on the A-4, A-6, and A-7 aircraft, and assisted in resolving fuze deficiencies in the original design. China Lake also engineered changes to the 300-pound penetrating warhead.

Maverick in Conflict. During **Operation Iraqi Freedom,** 918 AGM-65 Mavericks were used. In **Operation Enduring Freedom** (OEF) one AGM-65-G was used. Before and during OEF, WD helped define the Navy-unique requirements for Maverick; supported Air Force Foreign Military Sales Maverick customers; explored use of a replacement Laser Maverick seeker system; provided system engineering and technical support; trained personnel on Maverick use; and was responsible for the inventory, inspection, and recertification of Mavericks aboard returning aircraft carriers. During **Kosovo**, some 810 Mavericks were launched. VP-Squadrons carried out trouble-shooting of Harpoon and Maverick missile systems on various aircraft and evaluated Maverick support equipment. Mavericks were employed during **Desert Storm** by F-16s and A-10s to attack armored targets. Approximately 5,300 were used, mostly AGM-65B (TV-guided) and AGM-65D (imaging infrared-guided). Mavericks played a large part in the destruction of Iraq's military force. According to the Air Force, the weapon hit 85% of its targets. Maverick was also successfully used in **Vietnam**.

WD Current Role. China Lake's Tactical Weapons Office serves as Assistant Program Manager for Systems and Engineering and Class Desk for NAVAIR Defense Suppression Systems Office. China Lake supports all Navy/ Marine Corps Maverick variants from cradle to grave, conducts Insensitive Munitions (IM) and safety tests of the Maverick rocket motor, and assists in IM waiver requests. WD Point Mugu serves as Assistant Program Manager for Logistics and as the Fleet Support Team for Integrated Logistics Support. Raytheon is the contractor. [25]

Phalanx

Definition. The Mk 15 Phalanx Close-In Weapon System (CIWS) is a fast-reaction, computer-controlled rapid-fire 20-millimeter gun system providing U.S. Navy ships with a terminal defense against antiship missiles that have penetrated other Fleet defenses. It is designed to engage antiship cruise missiles and fixed-wing aircraft at short range. Incorporating a self-contained radar with integrated forward-looking infrared (FLIR), Phalanx automatically performs search, detecting, tracking, threat evaluation, firing, and kill assessments of targets. The latest version of the system, Block 1B, adds two new missions, anti-surface warfare to combat small-boat threats and anti-air warfare to defeat slow-moving suicide aircraft and helicopters. Both of these new missions require an operator in the loop. Displays have been added for the thermal imager and the search radar along with controls for the operator. The gun subsystem employs a Gatling-type gun consisting of a rotating cluster of six barrels firing 20-mm ammunition at either 3,000 or 4,500 rounds per minute.

WD Initial Role. WD's involvement with Phalanx has been in the area of test and evaluation. In 1969 a contract was awarded to General Dynamics for a closed-loop fire-control system to complement the SeaSparrow missile system. The first production model was completed in August 1979, and the first systems entered service in April 1980 aboard *USS America*. Phalanx was subsequently fitted on all surface warships of frigate size and above and all major amphibious warfare vessels as well as on combatant ships of 20 allied nations. In 1988 a Block I upgrade entered service and was capable of dealing with high-angle diving threats. The weapon system has steadily evolved since 1988. Block 1B was tested at the Land Range in 1997 and the Sea Range in 1998. It entered service on *USS Underwood* (FFG-36) in 1999. Phalanx has tested on the Land Range since the late 1970s.

Phalanx in Conflict. Phalanx has been the last line of close-in ship defense since it was first fielded in 1980. During **Operation Enduring Freedom**, Raytheon conducted operational testing on new software for Phalanx 1A at WD. The software incorporates more than 180 enhancements.

WD Current Role. Phalanx continues to test on the Land Range where hardware and software are checked out before any at-sea test phase. WD conducts aircraft tracking exercises for software development using everything from F-86s, A-4s, F/A-18s, and Cobra helos to Lear jets and Iskras. WD has also conducted hundreds of pre-action calibrations, gun-dispersion testing, towed-target firings, 175- and 155-shell firings, and Walleye firings. After testing on the WD ranges, systems are brought to Port Hueneme where they are installed on the remote-controlled Self-Defense Test Ship (SDTS). Here they are tested against live missiles that are homing on a target towed only 300 feet aft of the ship. This program has been extremely successful. Block 1B, which can engage surface targets, will be installed on most Navy surface combatant ships old and new for self-protection against advanced antiship cruise missiles that leak through the outer layers of defense, armed-small-boat swarm attacks, suicide boat and aircraft attacks. All existing Phalanx systems in the United States Navy will be upgraded to the Block 1B configuration by FY10. Phalanx has been sold to numerous foreign countries, including England, Canada, Egypt, Japan, Greece, and Bahrain.

WD Current Role. Phalanx continues to evolve. A new system called SeaRAM that replaces the gun in Phalanx with an 11-cell RAM missile guide is in development. SeaRAM includes a radar upgrade with a new RF digital signal generator, a new mixer, a new programmable signal processor, and a new antenna configuration that will improve system sensitivity by about 12 decibels to support the RAM missile envelope. The same radar upgrades will be retrofitted into Phalanx Block 1B along with a new commercial off-the-shelf-based weapon-control-group computer, a new FLIR, and a TV camera. Both new systems are expected to cycle through the Land Range for testing in FY05 before proceeding to the Sea Range for testing on SDTS in FY05/06. [26]

Phoenix

Definition. Phoenix is a long-range, all-weather, radar-guided air-to-air missile carried on the Grumman F-14 Tomcat. Phoenix, the Navy's only long-range air-to-air missile, is mated with either the AWG-9 or AWG-17 radar/fire-control system, which can track up to six Phoenix missiles fired against separate targets simultaneously. The improved Phoenix, the AIM-54C, was designed to counter projected threat tactical aircraft and cruise missiles. Phoenix can also be set to home on jamming signals, making life very difficult for enemy jamming aircraft. The AIM-54 ECCM/Sealed missile contains improved electronic counter-countermeasure capabilities. Phoenix has a solid-propellant rocket motor that propels the 13-foot-long missile at speeds in excess of 3,000 mph to a range greater than 115 miles. The missile's semi-active and active radar guidance system is difficult to jam, and the proximity-fuzed 135-pound high-explosive warhead makes Phoenix a very lethal weapon.

WD Role. WD's involvement with Phoenix has been in the area of test and evaluation and extensive technical and design support. Phoenix was developed in the 1960s as a counter to the threat of Soviet bombers attempting to attack Navy carriers, and Hughes was selected as the prime contractor in 1962. The AIM-54A became operational in 1974, and production ended in 1981. The AIM-54C entered service in 1985 and production was completed in 1993. The sealed version was delivered in 1986. WD developed improved fuzing components for the AIM-54, including in-house design and fabrication of an engineering model of the FSU-10A integrated warhead/propulsion safety and arming device. WD also developed the documentation package to allow competitive procurement and provided the engineering and production management support to bring Raytheon online as a second source for missile production. At Point Mugu, the F-14 Weapons System Integration Laboratory supports software and avionics integration for the F-14 Tomcat and Phoenix missile systems. Through the years, WD built and operated hardware-in-the-loop facilities; performed all-up-round acceptance testing, telemetry and engineering build-ups, flight test analysis, and configuration management; and prepared technical documentation.

Phoenix in Conflict. With the overthrow of the Shah of Iran in 1979**,** testing of the improved AIM-54C began at Point Mugu. At about the same time, revolutionary forces were taking over the F-14A and AIM-54A equipment in Iran, which necessitated a crash program at Point Mugu to develop counter-countermeasures that would defeat the AIM-54 and ensure that the new F-14A/AIM-54Cs could not be compromised by the earlier system.

Six-on-Six Test

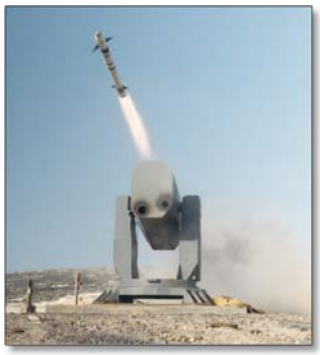
Point Mugu developmental testing included a spectacular six-on-six test before a congressional committee. The test demonstrated that the weapon system could simultaneously acquire and track six targets and then launch and guide six missiles, each to a selected target. Phoenix has rarely been used in conflict because the rules of engagement do not allow use beyond visual range. [27]

RAM

Definition. The RIM-116A Rolling Airframe Missile (RAM) is a lightweight, quick-reaction, high-firepower, surface-to-air weapon designed to counter antiship missiles. There are well more than 100,000 in the world's inventory today. RAM is a joint U.S. and German venture to design an effective, low-cost, ship self-defense system. RAM is a 5-inch passive dual-mode radio frequency (RF) and infrared (IR) fire-and-forget missile that uses Sidewinder technology for the warhead and rocket motor. Because of its high-tech guidance system, RAM requires no shipboard support after the missile is launched. RAM is effective against a wide spectrum of threats and it supplements Phalanx and SeaSparrow in the ship's defensive arsenal. RAM is currently installed, or planned for installation, on more than 80 U.S. Navy, 28 German Navy, and three Korean ships.

WD Initial Role. China Lake was the U.S. government's lead technical agent for the development of the RAM. Initial development began in 1974, and production was initiated in 1987. But, in 1990, while developing the Block Zero missile, the program suffered a number of problems and was in danger of being cancelled. China Lake was tasked to perform the Design Agent role to get the program back on track. After extensive design changes to make the missile more producible and more reliable, another test firing sequence began. This time the missile worked flawlessly, received approval for full rate production, and by 1992 the first ship was fitted with RAM. The first Fleet firing occurred in 1995 from *USS Peleliu*. In 1999, RAM Block I provided an improved infrared seeker, and a new active optical target detector. In 2000-2001, WD has assisted, as the Acquisition Engineering Agent, in the award of a full-rate production contract, provided production support and missile logistics**,** achieved accreditation of a RAM missile simulation, performed concept studies for product improvement, and supported extensive missile testing. RAM has been fired in more than 150 flight tests to date, resulting in a success rate greater than 95%. A capability against helicopter, aircraft, and surface targets is currently being developed and is expected to undergo operational testing in FY05. In addition a SeaRAM is also being developed for smaller ships.

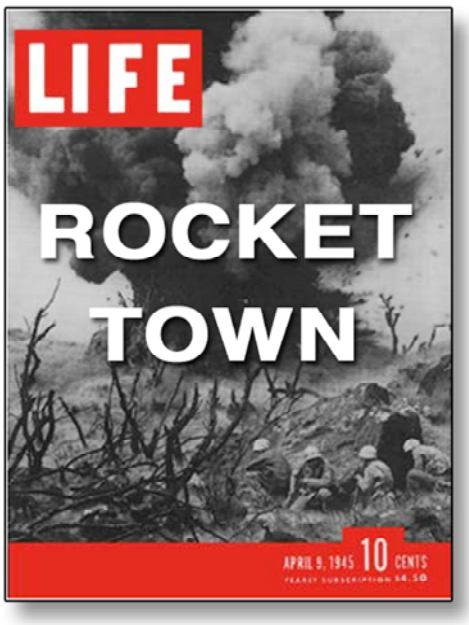
RAM in Conflict. RAM is currently in service on several classes of ships in the U.S. and German navies. Some 600 launchers have been produced, and some 230 systems acquired or ordered. During **Operation Enduring Freedom**, WD conducted open-ocean testing of RAM aboard an amphibious ship. This followed RAM at-sea tests aboard *USS Kitty Hawk. Essex, Germantown,* and *Fort McHenry*. During **Kosovo**, the WD RAM Test Team conducted a RAM Block 1 missile flight against a diving MQM-8G Vandal drone target on the Sea Range. During **Desert Fox**, WD successfully conducted the first dual developmental-testing launch of RAM Block 1 missiles against an MM-38 Exocet target on the Sea Range. In another test, two RAM missiles were fired against a Harpoon missile launched as a target from an F/A-18.



WD Current Role. China Lake is the Acquisition Engineering Agent for the Block I missile. China Lake simulations are accredited for pre/post flight test predictions and comprehensive performance analyses against current real world cruise missile threats. WD is also responsible for IR measurement and IR model development to support simulation. China Lake is designated the design agent for developing the rocket motor for the future RAM kinematic upgrade. The WD Sea and Land ranges are used for operational and developmental testing. Raytheon Missile Systems serves as the prime contractor. [28]

Rockets

Definition. Rockets are air- and surface-launched, unguided, ballistic trajectory weapons propelled by the controlled burning of energetic materials.



WD Initial Role. In 1941 Pearl Harbor drove home a hard lesson in naval air strike warfare: there was a great need for superior aircraft weapons. And in 1943 the first word of German aircraft rockets reverberated throughout the U.S. with headlines like "Nazis' New Air Rockets Caught Our Side Napping." It was clear that .50-caliber aircraft machine guns were ineffective against improved enemy armor, and a crash program was begun to develop forward-firing aircraft rockets to arm thousands of aircraft. China Lake (then known as the Naval Ordnance Test Station (NOTS), Inyokern) was established as a proving ground for developmental rockets.

Early rockets developed by the California Institute of Technology (Caltech)/China Lake team included the 2.75-, 3.5-, and 5.0-inch aircraft rockets; the 5.0-inch High-Velocity Aircraft Rocket (HVAR) Holy Moses; and the 11.75-inch Tiny Tim. The 3.5-inch fixed-fin rocket was the first forward-firing aircraft rocket used by American troops during World War II. Within nine months after the program began, Fleet aircraft were equipped with the rockets. These and the 5.0-inch Holy Moses were used extensively to weaken enemy resistance.

$100,000,000 Per Month

By the spring of 1944, rockets were becoming major weapons of war. The Army was procuring rockets to the tune of $150,000,000 a year. The Navy had 1,200 war plants turning out rockets and was spending eight times that amount—its expenditure for rocket weapons in 1945 was $100,000,000 per month. *Life Magazine* gave China Lake/NOTS the title "Rocket Town" in a featured article in 1948. By 1973, more than 50,000,000 2.75-inch rockets had been produced for the military.

Related work included the 5.0-inch bombardment rocket (BOMROC) system and several rocket-assisted projectiles (RAPs). Work on RAPs evolved over the years to include extended-range guided projectiles, such as the Anti-Radiation Projectile (ARP). Research and development included rocket propellants at the China Lake Pilot Plant, rocket launchers, rocket sights, new propellant grains, and new manufacturing processes. The Pilot Plant produced hundreds of thousands of complete weapons ready for shipment to combat theaters.

Early rocket work laid the foundation for China Lake's later efforts in rockets, missiles, propellants, warheads, launchers,

and fire-control systems. In 1950 China Lake undertook a project on a crash basis to meet urgent requirements in Korea, producing a simple pod-launcher that became the prototype of most of the FFAR launchers in use today. The launcher was developed, suitable for industrial manufacture, within four months from the start of the program. China Lake's rocketry expertise was instrumental in establishing its guided missile programs.

Early China Lake products also included spin-stabilized bombardment rockets and special-purpose rockets that were used for propelling line charges and sampling atomic clouds. Folding-fin aircraft rockets (FFARs) were another highly successful China Lake product, and this major technological contribution is used by the Army, Navy, Air Force, and Marine Corps to this day. They became, and continue to be, a principal helicopter weapon for all services.

Rockets in Conflict

Tiny Tim. This missile was developed by the Caltech/China Lake team. Far from being tiny, this high-speed air-launched, unguided rocket was, by prevailing standards, huge—with an 11.75-inch diameter and a 500-pound warhead. It was effective against ships, especially those that were heavily protected. The Tiny Tim rocket allowed weapon release more than a mile from the target. Although the rocket was introduced late in the war, Tiny Tim was very effective against fortified pillboxes and bunkers on the Japanese home islands. Tiny Tim was also used in the battle of Okinawa in April 1945.

Spin-Stabilized Bombardment Rockets (SSBRs). These missiles were developed by Caltech, tested at China Lake, and successfully used in **WWII** and **Vietnam**. The principal advantage of "spinners" was size. Finned rockets needed considerable length in proportion to their diameter for stability;

spinners could be much shorter and, unlike fix-finned rockets, could be launched from a tube. After WWII, China Lake took over the program and for nearly 20 years developed an entire family of SSBRs. They were used to provide surface-to-surface area neutralization and fire support for amphibious landings. They were launched from jeeps, trucks, PT boats, and rocket gunboats designed specifically for their use. The 5-inch, high-velocity spinner rocket was developed to give PT boats greater firepower, and the 5,000-yard-range version was rushed into service and distinguished itself in support of the troops hitting the beaches at Iwo Jima and Okinawa.

Holy Moses. This rocket was a Caltech/China Lake collaborative effort to develop a Navy aircraft rocket that had more combat "punch" than the British 3-inch rocket used during the early part of **World War II**. The design and development of the 5.0-inch motor was completed in 1944, and the weapon became one of the most effective rockets in service during World War II. Its steel-cased warhead could penetrate 1.5 inches of armor and four feet of reinforced concrete. Under Caltech direction, 100 rounds per day were manufactured and ferried daily by air from California to England, until 1,400 had been delivered.

General George S. Patton

Holy Moses was instrumental in the 513th Fighter Squadron's main action supporting General Patton's tank columns in their famous breakthrough at Constances, July 26-29, 1944. The squadron also played a key role in halting a heavy German counterattack on August 9 of that year. Major General B. E. Meyers of the Air Technical Service Command described Holy Moses as the "best antitank weapon of the war."

Holy Moses was used during the first air strike of the **Korean Conflict**, on July 3, 1950. The target was the airfield at Pyongyang, capitol of North Korea. Later, Holy Moses was successful in an early strike on the Wonsan oil refining factory. Corsairs launched eight Holy Moses, and Skyraiders launched two. Holy Moses established a new leadership in aviation ordnance for the U.S. that would be maintained for decades to come.

General Douglas MacArthur

When General MacArthur made an amphibious assault on Inchon, rockets again proved their worth. A flagship full of dignitaries, including Dr. Charles C. Lauritsen, and members of the press watched the attack. Lauritsen was the Caltech rocket pioneer who helped establish NOTS. In Lauritsen's words, the Caltech rockets "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, each firing a thousand of China Lake's powerful 5.0-inch, spin-stabilized barrage rockets. Holy Moses was also used successfully in **Vietnam**.

Ram Project/Antitank Aircraft Rocket (ATAR). Only days after the **Korean Conflict** erupted, the U.S. received information that JS (Joseph Stalin)-3 tanks were en route from Russia to North Korea. Rockets were urgently needed by U.S. forces to penetrate these heavily armored tanks. China Lake answered the call and designed, developed, tested, produced, and delivered 200 interim rockets to the Fleet within 28 days—and had the final design in production within three months of the initial request.

Everyone Pitched In

In July 1950, work on ATAR, also called Ram, involved the entire Station working around the clock. A critical part of the project was the fuze, which would have to function at the precise moment for optimum effect. Fuzes were assembled in the main hallways of China Lake's Michelson Laboratory by engineers, technicians, secretaries, and other laboratory employees. Anyone who could hold a soldering gun pitched in to get the job done, and by July 29, 200 weapons of an interim design had been sent by air to Korea.

ATAR was highly effective, capable of penetrating 17 inches of armor plate, and was credited with destroying numerous tanks. The Associated Press wrote that an F-4U Corsair carrying eight Rams had "a firepower greater than the broadside of a big, 2,200-ton destroyer firing all 5-in. guns." And *Life Magazine* memorialized Ram in a two-page photo spread showing the rocket demolishing a 30-ton tank. Secretary of the Navy Francis P. Matthews speculated that Ram's "timely availability to our fighting forces may contribute substantially to an early victory." As it turned out, Ram's use in Korea was limited, and it was removed from service in 1953. However, Ram was militarily significant in that the rocket showed that aircraft-projected weapons could defeat the heaviest mechanized land armor.

Rocket-Thrown Line Charge. During the 1950s, China Lake developed a forward-thrown explosive line for use in clearing mines, booby traps, and other obstacles from beaches. This provided a safe path for personnel and assault vehicles during amphibious operations. In 1962, the device was put in service use for the Navy and Marine Corps and successfully used in **Vietnam**. The device was fired from several hundred feet offshore and was capable of clearing a path 300 feet long and 40 feet wide. For the first time, assault forces could launch amphibious operations safely over cleared terrain. This technology has since found applications in terrain clearing weaponry now used by all U.S. services.

Mighty Mouse. This missile was designed, developed, and tested at China Lake and released for production in early 1950. The 2.75-inch FFAR, carried in pods and fired in clusters against targets, was effective against various battlefield targets and other non-lethal functions such as target marking, chaff dispersal, and illumination. China Lake was assigned the task of developing a small-caliber, high-performance FFAR for use by fighter and interceptor aircraft against high-speed heavy

bombers. About three million were produced during fiscal years 1953 and 1954. The new rocket soon acquired the nickname Mighty Mouse, a reference to the tiny but powerful comic-strip character created by cartoonist Paul Terry. According to one commander at the time, "The use of 'Mighty Mouse' against ground targets … was like going after a bug with a flyswatter instead of trying to stab him with a pencil." During **Vietnam**, Mighty Mouse was used for ground attacks with good effect. The rocket was standard armament for attack helicopters such as the Bell AH-1 Huey Cobra. All U.S. armed services used Mighty Mouse, and it was fired from more than 20 different platforms fitted with different versions of cylindrical pods accommodating seven or 19 rockets.

50 Million Rockets

Through the years the 2.75-inch rocket has steadily evolved and became, by far, the most common aircraft-launched rocket used by the U.S. armed forces. It has been manufactured with a common design by various companies. By 1973, some 50 million of these rockets had been produced for the armed forces.

Zuni. Named after the Zuni Indian tribe of the southwestern U.S., this 5.0-inch missile is an unguided, aircraft-launched, air-to-surface, folding-fin rocket. A four-round rocket pod firing Zunis was effective against various battlefield targets, including armored vehicles, revetments and other heavy targets. Zuni flew accurately and hit hard. The flare-head version of Zuni illuminated two square miles of target area. Zuni could also be used to deliver chaff and countermeasures. But its most important role was air-to-ground warfare. Produced at China Lake and released to the Fleet in 1960, Zuni was first used in combat in **Vietnam** and has remained in the Fleet inventory ever since. Literally millions of Zuni and Mighty Mouse rockets have been fired in conflict.

L.A. Times

"In a demonstration attack, eight Zunis were ripple-fired to slam perfectly across a ground target…Zuni is carried in groups of four beneath the wings of a fighter and can be fired singly, in pairs, in fours or eights…Its 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."

Rocket-Assisted Projectile. The 5-inch Rocket Assisted Projectile (RAP) program began at China Lake/ NOTS in 1962. The objective was to extend the range of the Navy's 5"/38 and 5"/54 shore bombardment guns, in order to keep firing ships safely beyond the range of enemy shore batteries. RAP added a solid propellant rocket motor to the spin-stabilized projectile to provide range extension while improving warhead and fuzing technology.

China Lake was the Technical Direction Agent developing the new projectiles, gun mount modifications, and fire control range tables. China Lake developed and qualified the rocket motor using high-performance fluorocarbon propellant. Static firing stands were built to test spin rates up to 300 revolutions per second. RAP included a proximity fuze, a blast-fragmentation warhead, and a solid propellant rocket motor. RAP provided a 50% increase in effective gun range and a 70% increase in the lethal warhead area. Full-rate production of the 5-inch/38 RAP began in 1967, and the first operational use was from the battleship *USS New Jersey* in Vietnam in 1968.

RAP was used in Vietnam, and a total of 50,000 5-inch/38 RAP projectiles were procured by the Navy. A RAP round was also produced for the Navy 5-inch/54 gun, and about 20,000 of those were put into the Fleet.

During the 1970s, China Lake successfully built and tested high-*g*, 5- and 8-inch propulsion systems for guided projectiles.

In 2003, the U.S. Army continued development of the gun-launched Extended Range Guided Munition (ERGM) based on this early but still relevant technology.

BOMROC. The BOMROC project was initiated in 1963 to increase the range and effectiveness of spin-stabilized bombardment rockets (SSBRs) using dual-thrust propulsion and new warhead materials. China Lake took the lead and developed new features that included more powerful motors; solid fluorocarbon propellants; longer burn times; greater reliability; longer storage life; new high-thermal-resistance materials; and new launching systems, tubes, power drives, and ammunition hoists. The result: a new family of rockets capable of achieving 18,000-yard ranges with the same lethality as that of previous 5,000-yard-range SSBRs. BOMROC was used successfully in **Vietnam.**

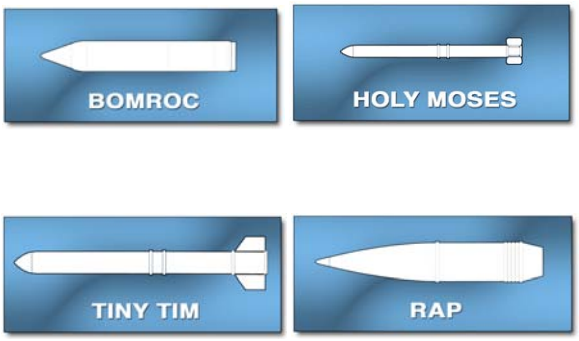
More Than 1,000 Projects Conducted. By the end of World War II, China Lake/NOTS had conducted more than 1,000 projects, and the base was well on its way to becoming the largest Navy-built, Navy-managed community. It had emerged as the Navy's lead laboratory, with the most completely instrumented ranges in the nation for rocket and midrange, guided-missile testing. The Station took on another major role in training pilots in the use of rocketry. Fleet squadrons were sent to train on NOTS' ranges, operating from Harvey Field at Inyokern, on their journey to combat in the Pacific. Here, aviators simulated diving attacks and fired their 3.5- and 5-inch aerial rockets at a white target on the desert floor. Between December 1943 and May 1944 about 28 Navy squadrons received training.

Rocket Science. The old cliché "It ain't rocket science" testifies to the complexity of that discipline. For example, in the 1940s Captain Deak Parsons wanted to develop what are now called "smart bombs." Parsons was a scientific naval officer known as the "Atomic Admiral" for his leadership role in developing the atomic bomb. He also helped establish the Salt Wells Pilot Plant, saved the Sidewinder missile from the budget ax, and helped ensure NOTS' R&D future.

But first he had to address a daunting question: With the Earth spinning at 900 miles an hour, where is an airplane or missile in relation to the spots on Earth where it took off from and where it wants to land? The answer, Parsons saw, was in the formula for the period of a pendulum: the square root of its length over gravity. One concept, called an 84-minute pendulum, says basically that if a pendulum can be stabilized and fooled into thinking it is the length of the Earth's radius, a person can tell, by measuring a rocket's acceleration and velocity against the pendulum, where the rocket is in relation to both launch point and intended target.

To turn that concept into hardware required a gyro-type platform of accelerometers to record the acceleration length along the three axes. The results had to be integrated twice in order to track, in three dimensions, the distance the rocket traveled relative to its target. Parsons' studies were the beginning of today's inertial navigation and guidance systems.

Today, with Trident submarine-launched missiles, course correction can be done from just one star, and the laser ring-gyro is so accurate that a missile fired from 6,500 miles away will hit extremely close to the target's bull's eye. Deak Parsons started it all–and today, China Lake is rocket science. [29]



Shrike

Definition. AGM-45 Shrike is a passive-homing air-to-ground missile whose mission is to home on and destroy radar transmitters used by the enemy to direct ground antiaircraft batteries and surface-to-air missiles. Shrike was the first missile to be mass-produced specifically for the U.S. antiradar mission. Shrike-On-Board was a quick-reaction program during **Vietnam** to put Shrike on destroyers.

WD Initial Role. Beginning in 1958, China Lake conceived, developed, and tested Shrike, the world's first successful antiradar missile, as a direct response to Fleet needs. China Lake pioneered antiradar (passive RF) guidance for Shrike, the High-Speed Antiradiation Missile (HARM), and the Advanced Antiradiation Guided Missile (AARGM). China Lake first developed Shrike, which begat HARM.

Shrike was guided by many of the same principles that guided Sidewinder. China Lake was lead laboratory for Shrike development and also produced the data package for dual-source production in order to establish competition and keep costs down. A contractor was selected for production design and initial production. A second competition was held to select another contractor for full production. This process resulted in significant savings.

As a result of this cost-effective approach, all subsequent Shrike production buys used this competitive process. Shrike has been used extensively in both the Navy and the Air Force and has been exported to more than a dozen countries.

Shrike in Conflict. Shrike was used in the Middle East, and by the U.S. Navy against Libya in 1986 and during the **Iran-Iraq War**. During **Vietnam**, China Lake personnel took Shrike-On-Board (SOB) to Destroyers in Southeast Asia for shipboard launch for the purpose of destroying or suppressing North Vietnamese coast-defense radars. SOB was used effectively in combat only 104 days after the program was initiated.

During the **Cuban Missile Crisis**, Shrike was still in development, but China Lake was requested to build 100 missiles on an emergency basis for possible use against the sophisticated Soviet surface-to-air-missile systems in Cuba. China Lake designed an alternate guidance section, built 50 of these missiles in-house, and directed private industry in the manufacture of the other 50 missiles. The program was completed in slightly more than six months, and the missiles were delivered to the Marines at Cherry Point.

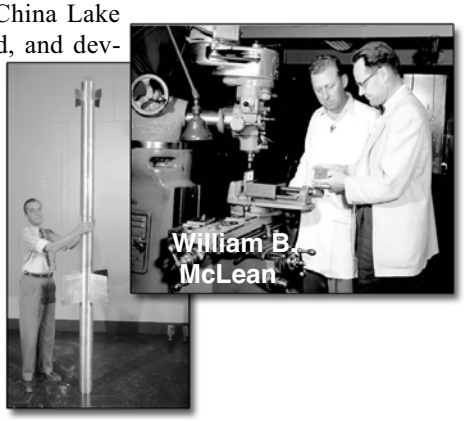
Since its 1965 combat debut, Shrike has become one of the most-fired guided missiles in history. Shrike's major limitation was that it had to be pointed towards the desired target radar prior to launch, and that the threat radar had to continue to radiate or Shrike would lose its lock. Shrike continued to evolve, and China Lake used its rapidly developing in-house antiradar technology such as the Electromagnetic Radiating Source Elimination (ERASE) Program, and the Anti-Radiation Projectile, to provide the foundation for the next generation of antiradar missiles—HARM (AGM-88). [30]

Sidewinder

Definition. Sidewinder is a supersonic, heat-seeking, air-to-air, guided missile carried by fighter aircraft. It has a high-explosive warhead and a passive infrared guidance system. It is carried by many types of aircraft, both fixed wing and helicopters. The currently deployed version, AIM-9M, consists of an infrared seeker with counter-counter-measures capability, double-delta canards used for steering, an active-optical proximity fuze for target detection and warhead initiation, a blast-fragmentation warhead, reduced-smoke rocket motor, honeycomb-core wings, and a unique "rolleron" system that controls roll rate during flight. The infrared seeker permits the pilot to launch the missile and then leave the area or take evasive action while the missile guides itself to the target.

Before Sidewinder, offensive weapons available to pilots in air-to-air combat were limited to guns and rockets. Guns required maneuvering close to the target's tail and precisely aiming the airplane (except for turreted guns used from larger aircraft with limited success). The time required to employ the gun made the pilot vulnerable to attack by other aircraft. Rockets could be fired from long range but were notoriously inaccurate and had to be fired in large numbers to be useful. Sidewinder had the range of a rocket, with less demanding aiming than a gun, and had a high probability of kill from the start. With more than 200,000 produced for 46 nations excluding the U.S., the AIM-9 is one of the oldest, least expensive, and most successful missiles in the entire U.S. weapons inventory.

WD Initial Role. China Lake conceived, designed, and developed the Sidewinder in the early 1950s under the direction of Dr. Bill McLean. China Lake developed and incorporated an IR seeker, a guidance and control system, and a propellant-gas generator to provide power for control. A prototype, the AIM-9A, was first fired in September 1953. Wally Schirra, the pilot who fired the first all-up Sidewinder, achieved later fame as an astronaut. Sidewinder was first deployed in July 1956, and the missile has steadily improved since.



The AIM-9B increased guidance time and range performance and allowed the missile to operate at higher altitudes. The AIM-9C incorporated a semi-active radar seeker; and the IR AIM-9D improved the launch envelope, seeker range, and fuzing. In the 1970s, China Lake co-developed active optical target detector (AOTD), the first active-optical fuze for Sidewinder, using solid-state lasers. Also in the 1970s, China Lake pursued Agile, an advanced dogfight missile combining China Lake technology advancements in thrust vector control (TVC), guidance, and targeting.

After AIM-9B, Sidewinder took separate paths of evolution within the Navy and the Air Force, each working on various modifications and upgrades. In 1972, China Lake initiated development of and tested the High-Altitude Performance (HAP) program. Using a Sidewinder in the front with a Sparrow propulsion unit, the HAP missile could engage high-altitude, high-speed targets. China Lake also developed many variations using the Sidewinder theme, including **Side-ARM,** an air-to-surface antiradar missile using the AIM-9C GCS. SideARM is carried on the Army Apache and the Marine Corps Super Cobra attack helicopters, and the AV-8B, for self-defense against anti-aircraft guns and SAM radars. The AGM-122A entered service in 1989.

General Dynamics developed the **Rolling-Airframe Missile (RAM)** using the Sidewinder rocket motor, warhead, and AOTD. In the early 1960s China Lake adapted the Sidewinder AIM-9D for surface-launch use as the Army's **Chaparral** Missile. Chaparral was a mobile light air defense system with

a turret mounted on a tracked vehicle carrying four missiles. The program was highly successful. Chaparral was available for foreign military sales and has been in service with 10 countries. In 1978, the Navy and Air Force once again merged their efforts and China Lake developed the AIM-9L with a new seeker and warhead, maneuverability improvements, and incorporating the AOTD. Later, the -9M was released to production in 1981. Improvements included enhanced counter-countermeasures capability and the employment of a reduced smoke rocket motor.

The latest version of Sidewinder, AIM-9X, again jointly developed with the Air Force with the Navy as lead service, rolled out (low rate initial production) on May 1, 2002. Full-rate production of the AIM-9X is due to begin in 2004, with a total production of more than 10,000 planned, about evenly split between the services. At China Lake, the Sidewinder program has been a fountainhead of technological development, and many of the advances in such fields as cryogenic cooling, seeker electronics, and fuzing systems have found application in other weapon systems. As the original inventor, China Lake will always be "home" to Sidewinder.

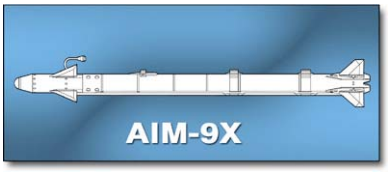
Sidewinder in Conflict. During **Operation Iraqi Freedom**, a WD Fleet Weapons Support Team provided technical assistance to Marine Aviation Logistics Squadron concerning the AIM-9 Coupling Ring, and another team supported Sidewinder usage on the newly deployed FA-18E/F.

In **Operation Enduring Freedom**, all U.S. and allied fighter aircraft carried Sidewinder. In 1994, **Bosnia**, NATO/U.S. forces shot down three Serbian G-4 Super Galebs with Air Force F-16s firing AIM-9s. During **Desert Storm**, coalition fighters downed 12 Iraqi aircraft with AIM-9s. In 1981, in the **Gulf of Sidra**, two F-14s downed two Libyan fighters using Sidewinder AIM-9Ls.

In the **Falkland Islands**, the British Sea Harrier killed 18 Argentine aircraft with AIM-9Ls. In 1982, in the **Bekaa Valley**, Syria, the Israeli Air Force shot down 51 Syrian MiGs using Sidewinders. In 1973, in the **Middle East**, Israel recorded the first **Chaparral** combat kill when a Syrian MiG-17 was shot down. **Vietnam** saw the first large-scale use of Sidewinder with 82 kills, and **Sea Chaparral** saw use by Navy ships. Sidewinder was the first deployed precision guided air-to-air weapon and was the first guided missile ever successfully used in combat when Nationalist Chinese forces engaged the Communist Chinese Air Force over the **Straits of Formosa** on Sept. 24, 1958. Six Sidewinders were fired from F-86 Sabres, downing four Communist MiG-17 fighters. It has been said that the availability of Sidewinder was a critical factor in heading off an invasion of Taiwan at that time.

Sidewinder was so successful it was adopted and copied by friend and foe alike. Many "look-alikes" have been built without license, such as the Russian AA-2 "Atoll" in the 1960s.

WD Current Role. For the AIM-9M, WD serves as the design agent, providing production support, data management, design changes, ECPs, modeling and simulation, and logistics. For the AIM-9X, WD is providing system engineering, system performance specifications, threat models and analysis, developmental testing, signal processor in the loop (SPIL) facility, and logistics. WD is also the primary government technical support for U.S. Navy variants. Raytheon is the prime contractor for AIM-9X. [31]



Skipper

Definition. The AGM-123 Skipper II is a short-range precision-attack missile, consisting of a modified Paveway II laser guidance system and a Mk 78 Shrike motor attached to a Mk 83 1,000-pound general-purpose bomb. It is a standoff anti-ship missile based on existing missile and bomb components. The rocket motor was derived from the AGM-45 Shrike antiradar missile.

WD Initial Role. China Lake designed and developed Skipper II as a powerful modification to the Paveway II family of guided bombs. The family of weapons concept is to use off-the-shelf components and to combine them to quickly provide the Fleet with urgently needed capabilities.

Skipper modifications to the Paveway II guidance unit included the addition of a roll gyro and digital autopilot that provided a low-level launch capability, including pull-up maneuver to avoid surface impact, trajectory shaping during midcourse guidance, and gravity-bias during terminal laser guidance. The Skipper I variant did not include a rocket motor and was never deployed. Skipper II used the Shrike rocket motor with lanyard activation of the motor after separation from the aircraft. The existing Mk 83 bomb and fuzing components remained unchanged. Development began in 1980, the concept was demonstrated in 1981, and Skipper II became operational in 1985.

China Lake built much of the initial flight test hardware, but because of increased demand, the basic design transitioned to industry. Later, other NAVAIR facilities built fully populated boards and validated the data package by building 350+ kits in house before placing further contracts with industry.

Skipper in Conflict. The AGM-123 Skipper was used successfully in 1991 in **Desert Storm**. The first combat use of Skipper was during the **Iran/Iraq War**, when a U.S. Navy A-6 Intruder struck the Iranian Frigate *Sahand* with three AGM-123s after the ship engaged U.S. Navy ships in the Strait of Hormuz. *Sahand* did not survive the engagement. Skipper IIs were also used to attack patrol boats hiding beneath oil platforms.

WD Current Role. Skipper II was active until the mid-1990s when it was phased out to make way for JDAM. Skippers were converted back to GBU-16 LGBs. Some Skipper design improvements, such as electromagnetic vulnerability hardening and moisture intrusion sealing, have been incorporated into Paveway II production laser-guided bomb hardware that is used today. [32]

Sparrow, SeaSparrow, ESSM

Definition. The AIM/RIM-7 Sparrow is an all-weather, medium-range, semiactive, air-to-air (AIM-7), and surface-to-air (RIM-7) missile, controlled by four delta wings and propelled by a dual-thrust solid-propellant rocket motor. During intercept, the launch aircraft illuminates the target with its radar throughout the missile's flight, as does the ship in a surface-launch engagement. At intercept, an active radio-frequency fuze detonates the high-explosive warhead. Sparrow is effective against high-performance aircraft and missiles.

SeaSparrow. The SeaSparrow surface-to-air missile system can destroy hostile aircraft and antiship missiles. The first shipboard launch took place in 1972. A vertical-launch system was tested in 1981, and SeaSparrow RIM-7M, along with the AIM-7M Air Sparrow, entered service in 1983. The AIM/RIM-7M missile upgrade (from the AIM-7F) has an enhanced radar seeker, improved electronic counter-countermeasures, digital microprocessing, a new warhead, and active radar fuze. Twelve NATO nations are involved in the program. AIM/RIM-7P began development in 1987, and deliveries of the –7P missile began in 1991. The –7P has a low-altitude guidance system that is effective against very low sea-skimming cruise missiles.

Evolved SeaSparrow Missile (ESSM). By 1995 ESSM engineering and manufacturing had begun. The RIM-162 is a kinematic improvement to the RIM-7 with a primary mission of destroying low altitude highly maneuverable anti-ship cruise missiles. The missile incorporates midcourse data links to provide ship based corrections during flight. ESSM is an international, cooperative, major upgrade of the RIM-7 NATO SeaSparrow. WD has served as the Technical Direction Agent since 1991. In March 2000, the first ESSM test launches were made at the White Sands Missile Range against a BQM-34 Firebee drone target, and in 2002 an intercept was made against a Harpoon missile configured as a target. The first ship launched test with a live warhead was in 2001. RIM-162 ESSM entered low-rate initial production in 2003.

WD Initial Role.

First U.S. Kill of an Airborne Target

At Point Mugu, Sparrow I, a radar-beam-riding missile known as Project Hotshot, began in 1946 and made the first U.S. kill of an airborne target in 1952.

Sparrow II, a semiactive radar weapon program, began in 1955 but was cancelled, and Sparrow III entered service in 1958 as the AIM-7C. In 1973 the AIM-7F entered operational test and evaluation, but the contractor encountered problems with reliability, production rates, and performance. WD, was tasked to work with Raytheon to correct operational deficiency and to qualify a second source. WD developed a documentation package, improved missile reliability, increased producibility, and solved most operational problems. WD developed the Mk 71 Mod 0 high-explosive continuous-rod warhead, the Mk 33 Mod 0 safety-arming device, the Mk 17 Mod 0 fuze-triggering device, and the DSU-26B target-detecting device. Successive developments have created a large family of Sparrow missiles. In the early 1970s, WD demonstrated the vertical launch of a Sparrow missile and its subsequent engagement and kill of a drone air target and proved the feasibility of the SeaSparrow concept.

Sparrow in Conflict. During **Desert Storm**, 25 Iraqi aircraft were shot down by Air Force and Navy aircrews using AIM-7s. Sparrow was used in the Middle East for many years. On February 13, 1981, an Israeli F-15 claimed a MiG-25 "Foxbat" shot down with an AIM-7. During **Vietnam,** about 7,500 AIM-7D and 25,000 AIM-7E missiles were built, and the missile was used heavily in Vietnam by the Navy and Air Force. The first combat kill was scored on June 7, 1965, when USN F-4B Phantoms shot down two MiG-17s. The missile evolved and an AIM-7E-2 dogfight version was developed. The -7E-3 had improved fuzing, and the –7E-4 was designed for high-power fighter radars. More than 50 aircraft were shot down by Sparrow during Vietnam.

WD Current Role. From 2000-2003, WD completed development/operational testing of the ESSM, supported transition to low-rate initial production, and assisted in developing a six-degree-of-freedom simulation model. WD qualified the AIM-7 for carriage on the F/A-18E/F, completed RIM-7P software upgrades, and completed the final Sparrow production run. With the Sparrow AIM/RIM-7 out of production, WD is involved in post-production Fleet support.

NATO Award

WD has provided Sparrow technical support to 20 countries through the years. A NATO consortium honored 17 WD engineers for supporting the German, and Royal Netherlands Navy. Raytheon and General Dynamics were the initial contractors during the 1970s. Today, Raytheon is the sole source for Sparrow and ESSM. As of 2001, more than 62,000 AIM-7 Air Sparrow missiles and more than 9,000 RIM-7 SeaSparrow missiles have been manufactured in the U.S. [33]

Standard Missile

Definition. Standard Missile (SM) is the Navy's primary surface-to-air Fleet defense weapon and is widely deployed on Navy ships. It is the descendant of an earlier missile project known as "Bumblebee," which included Terrier, Tartar, Talos, and Typhon. The newer SM concept minimized compatibility changes and was modular in design for ease of upgrade. SM, one of the Navy's most reliable weapons, began development in 1964, entered service in 1968, and has steadily evolved. The three main subtypes include SM-1, Standard ARM, and SM-2.

Standard ARM. A variant of SM, the AGM-78, was developed in 1968, as an air-launched version of the SM-1, to extend the range of the Shrike Missile. Used extensively in Vietnam, the AGM-78 was launched from the F-4G or F-105G "Wild Weasel" aircraft outside the range of enemy defenses and guided on the radar energy emitted by the target. Production began to improve the existing AGM-45 Shrike missile. In fact, the first Standard ARMs were equipped with Shrike's passive homing, target seeking head.

SM-2. The SM-2 Block I is an all-weather, ship-launched medium-range air defense missile, which added midcourse command guidance to increase area coverage. SM-2 Block II began in 1977 and added a new ordnance package and propulsion upgrade. SM-Block IIIB included an adjunct IR seeker, and Block IV is a longer range version using a booster for launch. WD helped develop the Mk 45 Mods 9 and 10 target-detecting devices (TDDs), the Mk 54 safety and arming (S-A) device, and the Mk 5 fuze contact device.

WD Initial Role. China Lake was both the design agent and technical direction agent for all SM fuzing (TDD, S-A device, and fuze contact device) and portions of the flight-termination system in the SM-1 and SM-2. The China Lake-developed Mk 45 TDD for SM is considered by many to be the world's premier missile fuze.

SM in Conflict. During **Operation Enduring Freedom**, WD established a Theater Ballistic Missile Defense (TBMD) Project Office and supported SM anti-TBM development. During the **Middle East** and the **Falklands** conflicts, Fleet ships launched and tested SM-1 and SM-2 against BQM-34, BQM-74, Vandal, and MA-31 aerial targets on the Sea Range. The SM-2 Block III was tested, with WD assistance, against targets on the Atlantic Fleet Weapons Test Facility in Puerto Rico. During the **Iran-Iraq war**, the cruiser *USS Wainwright* and frigate *USS Simpson* launched five SM-1s at the Iranian vessel *Joshan* and sank her. In 1982, several hundred AGM-78 SMs were sold to Israel, and the radar seekers were modified and used successfully in the **Bekaa Valley**. During **Vietnam,** an immediate need arose for a specialized TDD for Standard ARM. In only eight months, China Lake and the Naval Ordnance Laboratory, Corona, developed and fielded a new flash lamp active-optical TDD, the DSU-10/B. In only 90 days, China Lake developed the first active-optical fuze using solid-state lasers for Standard ARM. The DSU-15 for Sidewinder, and the DSU-19 for HARM were also developed. The Air Force used Standard ARM extensively to destroy North Vietnamese radars that controlled anti-aircraft guns and missiles. In 1972 the guided missile frigate *Sterett* downed three MiGs (March 30) with a salvo of Terrier missiles during the Dong Hoi engagement on April 19. The *Sterett* then launched a second salvo of Terriers at a surface-to-surface missile, destroying it in midair.

First TBMD Sea-Based Intercept. WD has supported the development and testing of the SM 3 (SM-3), a variant of the SM that fires from an Aegis cruiser, intercepting a ballistic missile in the exo-atmosphere. During 2002, WD participated in three successful flight tests at the Pacific Missile Range Facility (PMRF) in Kauai, HI, resulting in the first ever sea-based ballistic missile intercepts. These flight tests were preceded by extensive design reviews, modeling analyses, and component-level tests. Contributions made by WD were in the areas of IR seeker, guidance and control, and propulsion.

WD Current Role. WD is the technical direction agent of NAVSEA for the Mk 45 Mods 9, 10, and 14 TDDs and the technical direction and design agent for the S-A device, arming-firing device, and fuze contact device. China Lake maintains a computer-in-the-loop (CIL) facility for software development and TDD tests. WD developed and maintains a new engineering simulation, GENSIM, used to predict the performance of the Mk 45 TDD. WD conducted blow-down wind-tunnel tests to qualify the Mods 9, 10, and 14 TDDs. For the cancelled SM Block IVA program, WD developed an accurate method of field testing forward-looking fuzes, using artillery shells as targets and consulted on IR seeker development. WD is also funded to develop new S-A technology using micro electro-mechanical systems technology. WD supports development of the SM-3 missile with sea-based kinetic-energy boost-phase intercept-missile technology. China Lake works on the kinetic warhead, the third-stage rocket motor, and axial propulsion. Raytheon is the SM prime contractor. More than 20,000 SMs have been produced and exported to more than a dozen countries. WD will aid in development planning and contract formulation for the SM-6 program, scheduled to begin in 2004. [34]

Tomahawk

Definition. Tomahawk is a long-range, surface-to-surface, guided, subsonic cruise missile used for land attack from submarines, and surface ships. Tomahawk flies at extremely low altitudes at high sub-sonic speeds and over evasive routes for increased survivability. Targets are often high-value land assets in high-threat areas. Radar detection of the Tomahawk is difficult because of the missile's low radar cross section and low-altitude flight. Infrared detection is difficult because the turbofan engine emits little heat. Tomahawk has inertial and terrain contour-matching radar guidance that uses a stored map reference on board to compare with the actual terrain to determine the missile's position. Terminal guidance is provided by the optical Digital Scene Matching Area Correlation System, which compares a stored image of a target with the actual target image. Tomahawk has two warhead configurations: a 1,000-pound blast/fragmentation unitary warhead and a general-purpose bomblet dispenser.

WD Initial Role. Surface-launched cruise missile development began in 1972. Tomahawk's first developmental flight tests and simulations were conducted at Point Mugu in the mid 1970s, and in 1978 the first submarine launch was made off Point Mugu. In the 1970s, Point Mugu developed the Cast Glance High-Altitude Photographic System that supported Tomahawk tests, and in the early 1980s, China Lake became the principal support laboratory and applied thrust vector control (TVC) steering to Tomahawk. In addition, WD developed a second production source (dual source) for the missile resulting in improved reliability and significantly reduced unit cost. WD also was the Deputy Program Manager for the rocket motors, managing the rocket motor design and procuring the units for the all-up-round. For the Block III upgrade, WD developed a new lightweight warhead and fuze. Tomahawk Initial Operational Capability was achieved in 1983.

Tomahawk in Conflict. During **Operation Iraqi Freedom,** the Navy launched 802 BGM-109 Tomahawks. On the first night of major air operations, more than 100 missiles stripped out the ring of high-power low-frequency radars surrounding Baghdad and destroyed SA-2 and SA-3 sites and airfields. In **Operation Enduring Freedom**, 74 Tomahawks were launched, including 22 from *USS Mobile Bay*. In 1999, the British launched their first Tomahawk from a submarine in a test on the Sea Range. Later, in battle, six ships and three submarines from two U.S. battle groups and one U.K. submarine launched 238 missiles. In 1998, during **Operation Desert Fox**, U.S. and British forces launched 415 cruise missiles against Iraqi targets. In 1996 during **Operation Desert Strike,** 31 missiles were fired. In 1995, in **Operation Deliberate Force,** 13 were fired. In 1993 **Operation Bushwacker**, 23 were fired at the Iraqi intelligence headquarters in Baghdad in retaliation for an alleged plot to assassinate former President Bush. That same year, 45 Tomahawks were fired in **Operation Southern Watch**. In 1992, during the **Bosnian Conflict**, 13 Tomahawks were fired. Tomahawk's first operational use was immensely successful in **Operation Desert Storm**, 1991. A total of 288 Tomahawks were fired with a 98% launch success rate. Tomahawk was one of only two systems used to strike targets in downtown Baghdad. Since the Gulf War, the Navy has improved responsiveness, target penetration, range, and accuracy. China Lake designed, developed, and qualified the WDU-36 warhead in only 48 months to meet accelerated requirements. The WDU-36 uses a new warhead material, based upon prior China Lake warhead technology investigations. China Lake was also the Navy's Lead T&E Agent for Cruise Missiles.

WD Current Role. In March 2002, a Tomahawk was launched in an 860-mile successful test flight from the submarine *USS Bremerton* submerged on the Sea Range. The WD/Raytheon Tactical Tomahawk (TACTOM) team conducted the first free flight of Block IV, demonstrating in-flight retargeting and UHF satellite communications. The TACTOM team later demonstrated mission planning onboard the launch platform, in-flight retargeting, loiter and battle damage assessment capability, and in-flight health and status reports. The team also developed the Tomahawk Inflight Missile Simulator Pod and integrated it onto the F/A-18. The pod greatly reduced testing costs for missile updates. During 2000 and 2001, WD supported three major efforts, including the Penetrator Variant for deep targets, Tactical Tomahawk, and Block II/III. China Lake is the Navy's Principal Support Activity for the Tomahawk, the Acquisition Engineering Agent for the all-up round, the Software Engineering Agent and the Engineering Design Agent for the Tactical Tomahawk Penetrator Variant Warhead. [35]

Walleye

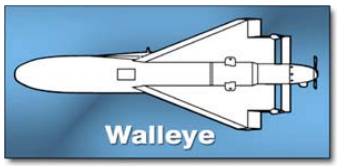
Definition. The AGM-62 Walleye is a precision-guided (television) air-to-surface glide weapon. It is used primarily against targets such as fuel tanks, tunnels, bridges, radar sites, port facilities, and ammunition depots. Walleye I and II are linear shaped charge warheads fitted with a TV seeker head, a set of aerodynamic control surfaces, and a tail-mounted datalink. The weapon has evolved into numerous versions, including the original Walleye I Extended Range Data Link (ERDL), Walleye II, and the Walleye II ERDL.

WD Role. China Lake conceived, designed, developed, and tested Walleye—the first precision-guided air-to-surface weapon. China Lake was the lead laboratory for the entire development, from concept to production.

The highly effective linear-shaped-charge warhead, designed by China Lake, was basically a cylindrical bar of explosive with an eight-pointed-star-shaped cross section encased in a steel shell. When detonated from the aft surface, the warhead created eight high-speed jets of explosive blast energy and steel, very effective at severing hard target structures such as steel bridges. The fuze and safety-arming device were designed by the Naval Ordnance Laboratory (NOL), Corona, California. (NOL moved to China Lake in 1970.) The fuze was a first-of-its-kind design that deployed an erectable probe into the air stream after launch, providing the energy to arm the fuze. Upon impact, a contact sensor closed a switch, which fired the detonators to initiate the shaped-charge warhead.

China Lake also developed the video/control data link that was the first tactical link of its kind. This data link has evolved into the Navy's tactical data link and is currently used with other systems such as SLAM. In January 1963, a Walleye released from a YA-4B made a direct impact on its target at China Lake in the first demonstration of Walleye's automatic-homing feature. Walleye was fielded in 1967 and proved its unsurpassed accuracy in combat. The Navy and the Air Force began combat tests in **Vietnam** during August 1967 and achieved excellent results against targets that gave a strong contrast. Walleye comprised about 6% of the total number of precision-guided munitions employed.

Walleye in Conflict. During **Desert Storm**, Walleyes were dropped from A-7E Corsairs from the aircraft carrier *USS John F. Kennedy* and 133 Walleye II (AGM-62B) were expended. During **Vietnam**, 512 Walleyes were used in tactical combat missions by the Navy and Air Force, and 92% of the weapons launched made direct hits on their targets. [36]



FLEET PROGRESS ON MANY FRONTS

FUTURE WARS – FUTURE WEAPONS

Network Centric Warfare (NCW). NCW uses a highly integrated and networked force structure to maximize launch platform and weapon system performance. FORCEnet—the emerging architecture of NCW—integrates sensors, networks, weapons, and decision aids into a powerful tool and places that tool in the hands of dispersed joint-service warfighters. Thus equipped, friendly forces can make rapid, accurate decisions; deliver decisive combat effects; and achieve battlefield dominance. With NCW, an intelligent, agile fighting force can slice through the fog of war and rapidly limit the adversaries' options.

Using the tools, technologies, and techniques of NCW, critical data are focused to create, in the words of Admiral Vern Clark, Chief of Naval Operations, "... the power of knowledge, instead of the distraction of multiple pieces of information." NCW harnesses that power so that it can be used to make the right decision, at the right time and in the right place.

Increasingly, the right decision in naval combat involves the use of precision-guided munitions. To maximize their enormous capability, these weapons (JDAM and JSOW, among others) depend on specific, timely, highly precise data from a variety of sources. WD is an international leader in the technology and techniques necessary to transmit up-to-the-second retargeting data to weapons already inbound on the attack. Division scientists and engineers are continually assessing current and future sensors, networks, and decision aids. WD also conducts live tests and demonstrations of actual weapon systems on the huge air, land, and sea test-range complex.

Using facilities such as the Integrated Battlespace Arena (IBAR), scientists, engineers, and analysts combine simulated and virtual assets to create advanced, computer-controlled combat scenarios. The "virtually" combined systems are analyzed to help identify additional capabilities for NCW tactics and techniques. The F/A-18 Advanced Weapons Laboratory (AWL) and the F-14 and EA-6B Weapon System Support Activities (WSSAs) integrate their respective platforms with a profusion of computers, sensors, and systems to ensure the interoperability that is at the heart of NCW. WD provides warfighters with the network centric warfighting power to secure battlefield dominance.

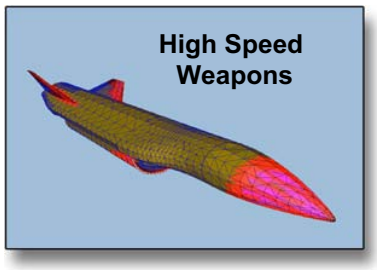
WD NCW organizations and facilities include the Weapons Engagement Office, Interoperability Test/Training and Experimentation Complex, E-2C Systems Test and Evaluation Laboratory, Maritime Surveillance Aircraft Facilities, F/A-18 AWL, EA-6B Airborne Electronic Attack (AEA) Laboratory, F-14 WSSA, and the new NCW OpCenter at Point Mugu. Among WD-developed NCW assets are the Tactical Dissemination Module (TDM) and the Digital Precision Strike Suite (DPSS). [37]

Future Ordnance Systems. The Weapons Division is now working on the weapons of tomorrow. Future ordnance systems will include improved reactive composite cases and impulsive energy weapons with flux compression, very high velocity directional fragments, and electromagnetic pulse (EMP).

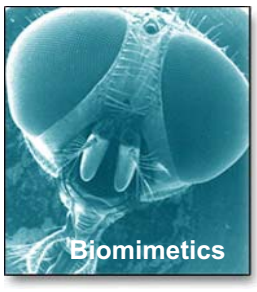
New explosive fills in development contain reactive metal enhancement, super brisant, and thermobaric qualities; and directional, super/hyper sonic, and mission responsive weapons are also in development. Conventional improvements will involve internal blast, battle damage assessment (BDA), initiation systems, multi-mode, miniature ESAD, sensors, submunition dispensing, penetration materials, and pyrophoric/fire start. Ordnance effectiveness will be enhanced via predictive model simulation and thermobaric modeling. Aircraft, guns, and ammunition of the future will include lead-free, medium-caliber ammunition primers and heat and water resistant "green" gun barrels. Aqueous based parts cleaning solvents will be used to meet modern environmental regulations. [10]

Teaming for Homeland Defense. As part of a NAVAIR initiative to provide greater assistance and support to the Coast Guard, NAVAIR WD and Naval Base Ventura County are exploring options to assist the Coast Guard as it executes its Deep Water Program, a multi-year, multi-phase effort to replace all its vessels, aircraft, and technology.

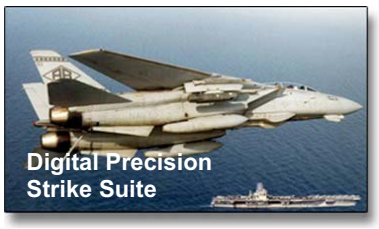
Energetics. NAVAIR maintains a full-spectrum energetics RDT&E capability to support the development and acquisition of Navy weapon systems. NAVAIR attracts top-ranked people and maintains a world-class energetics capability while partnering with industry and academia. Examples of this technology include CL-20, a molecule that enables the world's most powerful explosive currently available, and hypersonic propulsion systems for weapons that will exceed Mach 4. The NAVAIR energetics business base includes Navy air- and surface-launched weapons and other service and Defense Agency programs. Energetics constitutes over $100 million and 800+ workyears at NAVAIR WD annually including basic research in combustion sciences, firefighting technology, insensitive munitions, energetic materials, ordnance, and propulsion.



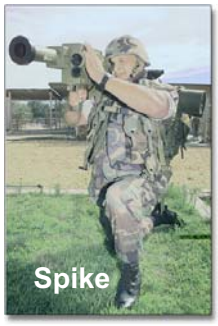
High-Speed Weapons. High-speed supersonic and hypersonic weapons can provide dramatic improvements in platform and weapons survivability and in the ability to engage time-critical targets, and to penetrate hardened and deeply buried targets. WD has conducted extensive work in the enabling technologies required to make such weapons a reality, including efforts in advanced airbreathing propulsion systems, blended body airframes, high-temperature materials, and ordnance package concepts. Programs are under way to demonstrate these technologies in flight testing.



Biomimetics. WD is studying fly eyes and other insects as part of a new biomimetic technology initiative. The common fly has an amazing ability to find moving targets in cluttered backgrounds, and then to land on moving "platforms." WD wants to know how flies do it so scientists and engineers can improve imaging sensors and signal processing.



Digital Precision Strike Suite (DPSS). DPSS provides a brand-new capability for the Fleet. It is a self-contained laptop system that increases the success for first-pass attacks with smart weapons. The computer correlates real-time target images from various sensors with existing geographical database imagery and assigns a latitude, longitude, and elevation to any part of the target. These targeting data are then transmitted to the aircraft and weapon. And it's all done by one operator, using a laptop computer, in less than a minute. Already tested in operations in the field, DPSS revolutionizes strike warfare.



Spike. The weapon the front-line troops have been waiting for, Spike is a man-portable, fire-and-forget, guided missile and launcher system that is very low cost and lightweight (three missiles can be carried in a Marine's backpack). Highly effective against helicopters and lightly armored vehicles, Spike, will also be a boon to warfighters in urban-assault scenarios. Concepts are currently in development.

LOGIR. LOGIR is a low cost accuracy enhancement kit for existing rockets. LOGIR will do for rockets what JDAM did for iron bombs. The LOGIR project began in 2000 and is still under way. Its primary objective is to significantly improve the warfighter's ability to address moving and fixed targets with an emphasis on moving targets. LOGIR allows the warfighter to designate the target using the existing targeting FLIR. Once designated, the pilot can fire the rocket and leave the area. LOGIR will use the FLIR targeting data to fly to the target, and acquire and track the target to weapon impact. Concepts are currently in development. [125]

CNO NAVAL POWER 21. FUTURE GOALS AND NAVAIR WD ACHIEVEMENTS

The Chief of Naval Operations (CNO) has outlined his operational vision for the 21st century in his plan, "Sea-Power 21: Sea Strike, Sea Shield, and Sea Basing." NAVAIR will serve as the lead Systems Command for Sea Strike. Key areas include persistent intelligence, surveillance, and reconnaissance (ISR); time sensitive strike; information operations; and ship-to-objective maneuvers. Below are a few examples of how NAVAIR WD is meeting the challenge.

CNO Goal: Acquire mobile targets more quickly and deliver an increasingly persistent and decisive volume of timely fire. In partnership with the Defense Advanced Research Projects Agency (DARPA), Office of Naval Research (ONR), and National Aeronautics and Space Administration (NASA), NAVAIR WD has conducted ground tests of full-scale ramjet engines for supersonic strike weapons. WD has established partnerships with Lockheed Martin in a Solid Fuel Ramjet Technology prototype for hypersonic strike weapons. In the area of guidance and control WD has directly supported Tactical Tomahawk (TACTOM), Tactical Dissemination Module (TDM), Digital Precision Strike Suite (DPSS), rapid precision targeting, Advanced Antiradiation Guided Missile (AARGM), Quick Bolt, and HARM Precision Navigation Upgrade (PNU) first flights, in addition to JSOW-C Unitary sled tests for deeply buried target destruction. WD is also developing and evaluating concepts for directed energy weapons, including high-power microwave (HPM) weapons and high-energy lasers.

Autonomous Operations

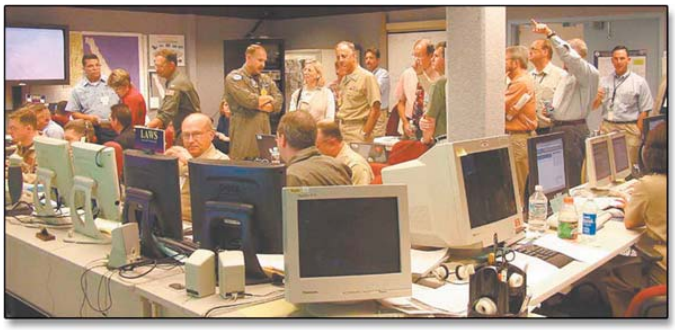
CNO Goal: Develop unmanned platforms for combat and reconnaissance in the air. In partnership with Northrop Grumman, WD has conducted the first flight of the Fire Scout UAV. In addition, WD has supported high-speed taxi and first flight tests of Northrop Grumman's X-47A Pegasus naval unmanned combat air vehicle (UCAV-N). WD also tested the weaponization of Predator for Operation Enduring Freedom.

CNO Goal: Sea Shield—Develop defenses against ballistic and cruise missiles. As the acquisition engineering agent for RAM, NAVAIR is developing afloat weapons. WD provided highly successful command-and-control and imagery support that resulted in a critical milestone in delivering a ballistic missile defense capability to the Fleet. NAVAIR's VX-30 provided testing support. In October 2002 NAVAIR WD successfully demonstrated a composite case solid rocket motor in support of the Missile Defense Agency's (MDA) kinetic-energy boost-phase intercept program. MDA has requested that NAVAIR be the flight-safety authority for launches from the Kodiak Launch Complex. In 2002 five Aegis ships fired on a single MA-31 precision guided target, the most surface combatants ever lined up to shoot at a supersonic skimming target. NAVAIR ranges supported the tests that made this possible.

CNO Goal: Develop better defense against small boats. WD is currently developing a concept for a small, low-cost, shoulder-launched, fire-and-forget missile called Spike. Spike will service the critical firepower needs of the U.S. Marine Corps and the Special Warfare community, and has application to the CNO's goal of developing better defense against small boats.

CNO Goal: Extend the persistence and staying power of our forward-deployed naval force. NAVAIR currently has TDM personnel in theater to provide advanced ground-to-air data links in support of Operation Enduring Freedom. In addition, NAVAIR's Engineering and Fleet Weapons Support Teams (FWSTs) are providing worldwide, on-site technical and training assistance to operational forces both ashore and afloat. Though it may be relatively invisible, WD developed technology that is helping to keep our ships at sea. Calcification-prevention tablets reduce calcium build-up in ship plumbing thereby reducing maintenance time and cost.

CNO Goal: Put intelligence, surveillance, and reconnaissance systems into one network. During Millennium Challenge 2002, DARPA developed unattended ground sensors at Superior Valley relayed intelligence on tracked vehicle traffic to a Predator UAV, which transmitted the data to the Strike Warfare Command Center at China Lake. From that location, the Carrier Air Wing Commander controlled Tactical Aircraft strikes using developmental systems that synthesize intelligence feeds. This revolutionary capability provided the commander with the common operational picture, enabling real-time re-tasking of airborne assets. Throughout this exercise, NAVAIR ranges were networked with other Army, Air Force, and Marine ranges. As a result of these successful efforts, the Joint Forces Command (JFCOM) designated NAVAIR Point Mugu as the Joint National Training Center (JNTC) regional hub for future joint experimentation.[38]



JOINT SERVICE

Teamwork is the cornerstone of NAVAIR's success. Each and every activity that China Lake and Point Mugu participate in—every test event, training mission, and laboratory experiment—is a team effort. Teamwork binds together the network of highly trained scientific, technical, and administrative personnel (military, civilian, and contractor) who carry out the NAVAIR mission.

Teamwork extends far beyond the geographic and organizational borders of NAVAIR. Customers from throughout the Navy bring their problems to China Lake and Point Mugu, expecting and finding the solutions that help to make the Navy the central element of the national defense structure.

And teamwork reaches across service boundaries to the Marine Corps, Army, Air Force, Coast Guard, and Homeland Defense Department. NAVAIR is at the forefront of joint-service activity: joint training, joint testing, joint experimentation, joint research, joint development, and joint acquisition.

Among the many joint ventures on which China Lake and Point Mugu have embarked with the sister services is establishment of a Warfare Response Network and a Homeland Defense Response Team. NAVAIR's western-most bases have made major developmental, test, and training contributions to the Department of Defense's (DOD) top weapon systems. The Land Range, Sea Range, and Electronic Combat Range (ECR) have hosted virtually every combatant aircraft in the DOD inventory, ranging from Air Force fighters and bombers and Army helicopters to developmental aircraft (e.g., the F-22 and Joint Strike Fighter (JSF) to joint-service UAVs). Special Forces units have roamed the deserts hills of Superior Valley, and Marine light armored vehicles have raced across the dry flats of Airport Lake during live-fire exercises. The ranges and laboratories have played principal roles in the Nation's largest joint-service battle experiments, and Point Mugu has been selected as the site of the U.S. Joint Forces Command's Regional Joint National Training Center.

Joint Activities/Partnerships

For a complete list of our partners including the Marine Corps, Air Force, Army, Coast Guard, other DOD agencies, international partners, industry partners, and educational institutions, please see *Joint Activities/Partnerships* page 160.

INTERNATIONAL SERVICE

The country's international partners benefit from the same principle of teamwork. The first Tomahawk firing from a British submarine took place on the Sea Range, and the Japanese Defense Force conducts annual training and missile-development exercises there. The Italian Air Force trains with HARM on the Land Range, and the Royal Danish Navy has participated in Evolved SeaSparrow Missile (ESSM) launches on the NAVAIR Ranges. Many countries send representatives to the F/A-18 AWL, and all North Atlantic Treaty Organization (NATO) countries benefit from NAVAIR-developed improvements to the Mk 82 series bombs. NAVAIR explosive ordnance disposal (EOD) units train with counterparts from Croatia to Thailand, and the Joint Tunnel Warfare Center welcomes representatives from many U.S. allies.

NATIONAL AND INTERNATIONAL FORUMS

WD has historically provided a leadership role in many professional societies. WD is on the Executive Committee of the Joint Army-Navy-NASA-Air Force Interagency Propulsion Committee (JANNAF); active in the American Institute of Aeronautics and Astronautics (AIAA), and chaired the 2000 Missile Sciences Conference; serves on the Missile Sciences Committee; chairs sessions for the Military Sensor Symposia (MSS) on Active Systems, and the MSS National/International conferences; and co-chairs sessions for the National Fire Control Symposium.

NATO Award

Internationally, WD is active in NATO and Technical Cooperation Program affairs, and chairs a panel on second generation military laser systems. For more than 20 years, this group introduced and investigated new laser systems that have been successfully produced. During three years (1996, 1998, 2001) the group conducted highly successful field trials and generated high quality reports on laser performance under severe atmospheric turbulence. In 2002 this group won the NATO Research and Technology Organization scientific achievement award over a field of 150 other NATO groups. This work has had positive impact. For example, the joint Army/Navy Foreign Comparative Test program evaluated a German LADAR obstacle avoidance system for helicopters which is now in production for special operations command platforms. In addition, activities in 3-D imaging LADAR, support the Cruise Missile Real-Time Retargeting (CMRTR) program.

WD also serves on the steering committee of the NATO Insensitive Munitions Information Center with representatives from the United Kingdom, Australia, and New Zealand. WD has also led several panels in propulsion, warheads, guidance, control, and fuzing. [40]

TECHNOLOGY TRANSFER

The Federal Laboratory Consortium (FLC), the primary national Federal technology transfer group, consists of more than 700 federal laboratories and centers and their parent departments and agencies. The FLC, originally established by China Lake in 1971 as the DOD Technology Laboratory Consortium for Technology Transfer, grew from 11 original laboratories in 1971 to 200 laboratories in 1975 under China Lake leadership. The FLC promotes and strengthens technology transfer nationwide. Through the years, thousands of government patents have been awarded with numerous applications to warfighting systems, a key means of staying ahead of U.S. adversaries.

WD transfer programs have included telecommunications on radar systems, video frequency data conversions, data displays, test facilities, and a design for an airport firefighting system for short takeoff and landing airports for the Federal Aviation Administration (FAA). Work was done in low-light-level television, voice scramblers, patrol car tracking, and personnel communication links for the Law Enforcement Assistance Administration. Biomedical ideas have been brought to life for the National Institute of Health, and an air-quality-control monitoring program conducted mapping of aerosols for the State of California. Other significant WD contributions resulted from investigations into wind, solar, and geothermal energy; solid waste conversion to clean burning fuel; and aircraft survivability. An explosive device was developed to clear fire lines for the Forest Service. [41]

CL-20. Most Significant Energetic Material in 50 Years. China Lake developed the most significant energetic ingredient in 50 years. CL-20 was a breakthrough in energetic materials with higher performance, minimum signature, and reduced-hazard characteristics. CL-20 has numerous military and commercial applications.

Automotive Air-Bag Sensors. A tiny micro-machined digital accelerometer designed by WD engineers as a guided-missile component is today at the heart of a life-saving system used throughout the world. In 1994, the Navy needed a means to accurately measure the distance traveled by the missile after launch—a computation necessary for arming the warhead-firing device at a safe distance from the launch aircraft. A China Lake engineer conceived of a precision, extremely robust, micro-machined, miniature accelerometer, which at the time did not exist. Working with a Small Business Innovation Research contractor, WD oversaw development of an accelerometer using microelectronic fabrication techniques (to ensure ease of manufacture and thus low per-unit cost) and operating with a single power supply. The device was also designed to be resistant to variations in supply voltage. The resulting accelerometer was incorporated into several warhead safe-arm devices. It was subsequently transitioned into millions of automobile crash-sensor air-bag-initiation systems by major foreign and domestic automobile manufacturers. The device, also used for hundreds of other consumer and industrial applications, is now marketed and sold internationally.[42]

Geophysical Warfare "Rainmakers." During the Vietnam Conflict, U.S. warfighters needed a way to interdict enemy traffic on the Ho Chi Minh Trail. "Project Popeye" helped answer the call. China Lake adapted its cloud-seeding technologies to enhance rainfall, thereby significantly deterring enemy activity on the trail. This highly successful China Lake technology was also used in hurricane abatement, fog control, and drought relief.

Ultrasonic Scanning. During Vietnam, China Lake pioneered logarithmic amplifiers for radar signal processing applications. In 1971 this technology was transferred to the Mayo Clinic and led to the development of the first ultrasonic body scanning equipment.

Stop-Action Video. China Lake invented the electromechanical shuttered video camera to provide non-smeared stop-action images of weapon test events. Today, this technology is used for commercial stop-action sports broadcasting. Since WWII, China Lake has been one of the most accomplished developers of range instrumentation. Other examples include real-time continuous x-ray systems, high-speed photography, and encrypted telemetry.

Chemiluminescent Light Sticks. During the Vietnam Conflict, U.S. warfighters needed emergency lighting for life rafts, downed flyer beacons, map reading, and damage evaluation. China Lake scientists answered the call with a chemiluminescent light stick. Today this technology is used commercially worldwide for novelty items, commercial fishing lures, and illumination sticks for emergency kits.

Geothermal Energy. China Lake is practically energy independent. This world-class resource ranks among the top 10 in total power output. While California and much of the nation have been in an energy crisis, China Lake has remained nearly energy independent since 1987. In 1964, geological engineers at China Lake first discovered the enormous geothermal potential on the northwest portion of the base. In the 1980s, wells were drilled and contracts were established with Southern California Edison to tap this valuable resource. Total energy savings since that time are on the order of $36 million. The Navy will save in excess of $500 million during the life of the contract. WD was assigned the lead role for all Navy geothermal effort, not geographically limited to China Lake. Two test wells have been drilled and the technical results are now being evaluated. Future energy potential is enormous. In addition, China Lake is the DOD lead laboratory for solar energy and has about one megawatt of photovoltaic (PV) systems installed, including the largest PV/diesel/battery hybrid in the world. The Energy Program Office has assisted with other PV installations for the Marines, Army, and Air Force.

Calcification-Prevention Tablets. Virtually every ship in the U.S. Navy today carries and uses a product invented by researchers at China Lake. The product isn't very big or expensive, but it saves the Navy more than $4 million dollars each year and is used by cruise ships, freighters, and other navies. For decades, the Navy dealt with the problem of calcium buildup in the sewer systems aboard ships. When urinals are flushed with sea water (which is well saturated with calcium), uric acid and other acid components cause precipitation of calcium carbonate, which builds up on the inside of the ship's plumbing. The traditional cure for pipes clogged by calcium deposits is expensive and time-consuming hydroblasting. China Lake scientists developed inexpensive, environmentally friendly, water-soluble polymers that are placed in the urinals in tablet form and release citric acid to bind the calcium in the flush water. This invention won the Office of Naval Research's Vice Admiral Harold G. Bowen Award in 1996. More than 1.5 million tablets per year are used by the Navy and trouble calls on the high seas have dropped by 90%.

HazMat Containers. Point Mugu has also been actively involved in helping develop new technologies for hazardous materials containers. More than 60 different types of containers are now in use at Navy/Army/Air Force facilities around the world. They are also now available on commercial carriers. [41]

Actuated Cable Cutters. In the early 1950s the Navy developed a blank, explosive, cartridge-actuated, cable cutter for emergency cable cutting for ship tow/transfer lines, helicopter supply lines, etc. In 1990, this technology transferred to private industry. Today, companies such as CACT CO and Hi-Shear Technologies, of Torrance, California, have developed advanced cartridge-actuated cutting tools that are used nationwide, as well as by many countries throughout the world by the police, sheriffs, SWAT teams, and fire departments, for cutting security bars, chains, and locks. These tools are also highly effective "jaws of life" for cutting through steering wheels and break pedals. The electric power line industry across the U. S. and in some foreign countries is now using cutters for cutting lines, bolts, and ground rods. These extremely portable devices are also indispensable for emergency relief during earthquakes, explosions, and other disasters. Cutters can also be remotely activated. Rescue workers use these devices for cutting rebar and other steel bars. For example, in the Oklahoma bombing, cutters were used by the fire department to rescue trapped individuals. [8]

PARTNERING WITH INDUSTRY AND ACADEMIA FLEET BENEFITS

Cooperative Research and Development Agreements (CRADAs). Since the early 1990s, the number of CRADAs at WD has continued to climb. Through 2003, WD has managed 155 CRADAs with industry partners that generated close to $17 million. The cumulative total cost avoidance value is estimated to be worth an additional $50 million; 19 new CRADAs were initiated in 2003 alone. Most agreements involve military-related technology, however some CRADAs involve commercial and educational projects. For example, in past years WD worked with San Diego State University, using their radiographic facility to scan the head of a beached whale to better understand how whales generate and propagate sound. And the Division used the radar cross section facility to assist a car maker in developing a radar to detect objects and avoid collision when a vehicle backs up. One CRADA holds hope for cleaner air by monitoring hazardous emissions, a previous partnership with Apple Computer improved computer networking, and another CRADA may help reduce sunglass glare and improve commercial satellites using a new wire-grid polarizer. A ring vortex gas-projection system may have medical, police, and military applications; new hydrofoil improvements hold promise for a new line of watercraft for recreation and public transportation.

Major China Lake CRADA partners include Raytheon, Alliant Techsystems, Inc. (ATK), Boeing, Lockheed Martin, Atlantic Research Corporation, and Northrop Grumman. Point Mugu partners include Biodeisel Industries, Inc., Roadable Aircraft International, Inc., American Hydrofoil Corporation, QuasArk America, Inc., Life-Safer, Inc., Lockheed Martin, Capital Broadcasting Corporation, Agro-Management Group, and Disaster Response Equipment, Inc. [41]

Commercial Service Agreements (CSAs). In the performance of its military mission, WD has acquired and developed specialized equipment and many one-of-a-kind facilities. WD's resident scientists and engineers constitute a significant scientific resource. Legislation allows the government to offer access to industry and academia through CSAs. Outside entities may tap and leverage WD resources and knowledge by contracting to perform tests and develop specialized goods and services using WD facilities, ranges, and laboratories. During 2003 WD initiated 25 CSAs and received more than $6 million for support work covering a wide range of technical areas. In addition, the processing time for CSAs has continually decreased. WD has entered into CSAs with a number of defense contractors including BAE, Boeing, Lockheed Martin, Northrop Grumman, and Raytheon. [43]

More Than 1,500 Patents

Patents with Commercial Potential. Since 1959, more than 1,500 patents have been issued at WD (1,051 at China Lake and 517 at Point Mugu). Some inventors hold more than 20 patents. During 2003, China Lake wrote 29 patent disclosures, 24 new patent applications, and 18 new patents were issued. Point Mugu wrote 26 patent disclosures, 19 new patent applications, and 19 new patents were issued.

Since the 1940s, scientists and engineers have created hundreds of inventions to solve technical problems associated with weapon development. These inventions cover a wide range of technical disciplines, including aerospace systems, data and image processing, electronic and electro-optical systems, optical materials and processes, energetic materials, mechanical systems, advanced materials, energy conversion, propulsion and propellant technologies, and sensors. A significant number of these inventions are patented and involve technology with commercial applications. The Web sites below include lists of patents that are licensable and those that have reverted to the public domain.

China Lake patents with commercial potential:
http://www.nawcwd.navy.mil/techtransfer/patentov.htm.

Point Mugu patents with commercial potential:
http://www.nawcwpns.navy.mil/~tt/Navy_patents.html. [41]

Educational Partnership Agreements (EPAs). Legislation encourages EPAs, and WD is proactively working with a variety of institutions. These relationships foster an open exchange of technical ideas and provide a synergy that is of great value to both communities. EPAs allow scientists, engineers, teachers, university professors, and students to collaborate and share ideas, equipment, and facilities in the pursuit of scientific research and education. WD has ongoing EPAs with New Mexico Institute of Technology, and with California State Polytechnic University, Pomona, California. [43]

ENVIRONMENTAL LEADERSHIP

From the stunning Native American rock art of China Lake's Coso Range to the rare Island Night Lizards of San Nicolas Island, WD's resources constitute an extraordinary national treasure. For more than 50 years, WD has exercised responsible, proactive stewardship.

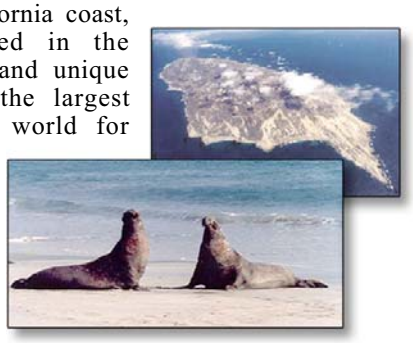
Unencroached with Room to Grow. Encroachment is a fact, to varying degrees, at all military installations. As the population grows, the issue naturally intensifies and many bases today are greatly affected by adjacent urban sprawl. However, of all DOD facilities, China Lake, located in a remote portion of the Mojave Desert, has the least potential to disturb the neighbors—more than one million acres, larger than the state of Rhode Island. Military activities impact less than 10% of the total land area. And the Sea Range, encompassing 36,000 square miles, is the Navy's largest test and evaluation facility. Business opportunities at WD have room to grow. In addition, WD is close to completing an Environmental Impact Statement (EIS) at China Lake. One EIS is already in place for the Sea Range. These studies will streamline the environmental approval process. WD RDT&E activities meet or exceed all state and federal clean air act, hazardous materials, and permitting requirements—opening the doors for new business.

Minimal 10% Impact. The vast majority of China Lake's land is a safety and security buffer and remains in a mostly pristine natural state. Locations for new facilities and specialized test events are carefully selected to minimize impact, and the staff scrutinizes virtually every mission-related activity to ensure that it complies with natural-resources laws and regulations. Ongoing formal cultural-resource inventories to identify archaeological, historical, and traditional properties have been conducted on more than 11,000 acres to date.

Dedicated Staff. Long-range resource planning, as well as day-to-day oversight, of scores of WD environmental projects, is carried out by a team of civil service professionals, ranging from archaeologists and ecologists to environmental engineers and augmented as needed by contract specialists. Community involvement is also encouraged. For example, the Friends of China Lake Archaeology, a self-help group of volunteers, logged more than 900 hours of work in the first half of 2003 to establish a federal curation facility on base.

Petrogylphs. China Lake protects the largest concentration of ancient rock art in the world. This area, 100 square miles of rugged mountain canyons inside the base boundaries, is a National Registered Historic Landmark. As a result of WD's unique stewardship, China Lake won the Governor's Award for Historic Preservation in 2003. Despite heightened security since the 2001 terrorist attacks, China Lake continues to provide public tours of the Coso petroglyphs.

San Nicolas Island. On WD's San Nicolas Island (SNI), 65 miles off the California coast, isolation has resulted in the evolution of distinct and unique taxa. The island is the largest breeding site in the world for California Sea Lions. Annually, more than 23,000 Elephant Seals, 100,000 California Sea Lions, and 500 Harbor Seals use the island beaches. WD has broken ground on an approved $12 million-dollar military-construction project to build a special pier to meet operational requirements. In addition, the pier will keep boats from beach landings that could disturb sensitive wildlife. SNI also has an outstanding cultural heritage. The Nicoleno Indians inhabited the island for at least 10,000 years, and more than 500 archaeological sites have been documented. WD protects and preserves the resources at SNI in the context of an Integrated Natural Resources Management Plan.



Management. During the last three years, WD developed aggressive management plans for preserving endangered species such as the Mojave Tui Chub, the Island Night Lizard, the Desert Tortoise, Mojave Ground Squirrel, the California Inyo Towheether, the Western Snowy Plover, California Brown Pelican, and the San Nicolas Island Fox. Plans protect birds from aircraft strike hazards, ravens from overpopulation, and pinnipeds from the impact of nearby missile launches.

Wild horses and burros, potentially at risk on runways, are rounded up annually and adopted out in a formal program in coordination with the Bureau of Land Management. China Lake cleared more than 100 acres of non-native vegetation that was depleting wildlife water sources and developed a Geographic Information System-based photographic database for identifying and protecting its 122 natural desert water sources.

Environmental Awards. In 2003 the Governor's Award for Historic Preservation was presented to China Lake for its long-standing heritage program that combines scientific, historic, recreation, and Native American values. No other military installation has been the recipient of such a prestigious award. In 2002, WD won the Chief of Naval Operations Environmental Award. The citation read in part, "Through your resourceful Natural Resource Program, you continue to effectively balance mission support with wildlife and land management through conservation education and conscientious environmental stewardship." [44]

SPACE PROJECTS—FLEET BENEFITS

Mars Exploration Rover (MER) 2004

The Weapons Division provides direct Fleet support for Naval aviation. WD has extensive experience in developing, perfecting, and testing military components and subsystems that have direct application to space missions. Although work for other government agencies represents only a very small fraction of our total workload, the Division is occasionally called upon by NASA to lend expertise to projects of national importance. Lessons learned from joint projects are mutually beneficial. WD's experience includes rocket motors (deceleration and stabilization of spacecraft), jet vane and thrust vector control systems (precision guidance and landing control), and radar systems (determining distances from landing surfaces). Since 1979, China Lake has been home to the National Parachute Test Range (NPTR). Any Federal agency can take advantage of the unique combination of assets and technical skills at NPTR. For example, the Forestry Service (airborne fire fighters), Special Forces, Air Force, Army, and Marines have all tested on NPTR. WD has proven experience in parachute RDT&E (special cables, bridles, and tethers often used in space missions), and emergency escape systems (manned sea landing/recovery). WD maintains the Land Range, where technicians evaluate all types of Navy test equipment (as well as Lunar and Mars vehicles).

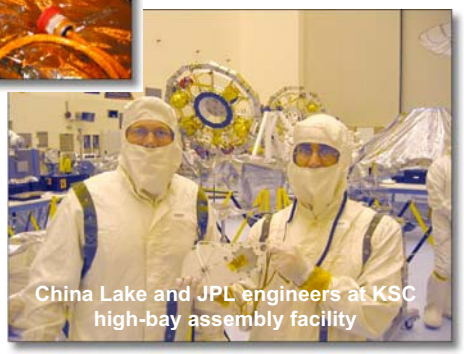
Fleet Benefits. WD's relationship with NASA is mutually beneficial. Lessons learned from joint projects help WD find solutions to Naval aviation problems. Lessons learned from the 2004 missions include developing the Zylon bridle that will allow increased deployment velocities and decreased weight and volume for future Naval aviation parachute systems. Zylon lines may one day replace heavy, cumbersome aircraft tie-downs on carrier decks. The radar altimeter may be considered for high-altitude, low opening (HALO) parachute systems. Also, the descent rate limiter is being considered for use in reusable reefing systems for Army cargo and Navy special forces parachute systems.

Mars Exploration Rover (MER) 2004. Continuing a 61-year relationship with the California Institute of Technology (Caltech) and a long-time relationship with NASA and the Jet Propulsion Laboratory (JPL, a division of Caltech), China Lake was asked to assist on the 2004 missions. (China Lake was established in 1943 as a place to test and evaluate Caltech rockets during World War II.) The success of *Spirit*, the Rover that landed on January 4, and *Opportunity*, that landed January 24, can be attributed in part to the innovation and technical expertise of China Lake's Egress and Survival Systems Division. The team has applied their extensive Navy parachute and egress expertise to assist NASA and JPL Mars missions for the past 10 years. The NAVAIR team accomplished the following tasks for the 2004 missions:

Zylon Bridle. China Lake designed, built, and assisted in the installation of the bridle system onto each spacecraft. The bridle connects the MER backshell to the Lander. Zylon, a new ultra-high-strength fiber, was subjected to strength and environmental testing, and the required joints were designed and tested. Prototypes were fabricated, qualification tests conducted, and finally three flight-quality units were fabricated at China Lake to support the two missions plus a "flight spare." Each bridle contained 22 digital communication wires, allowing each Lander to command the retro-rockets. The bridles worked perfectly and now remain on the surface of Mars.

Descent Rate Limiter (DRL). China Lake and JPL jointly developed the DRL. In addition, China Lake tested and qualified the mechanism, and installed it on each spacecraft at Cape Canaveral's Kennedy Space Center. The DRL allows the Lander to slowly drop to the end of the bridle. Initial tests were conducted at China Lake's Crew Systems drop tower, but results were unsatisfactory. Late in the program, JPL chose to abandon that design and, with China Lake's assistance, designed a totally new device. This design proved suitable, and several flight-quality units were qualified for use.


China Lake engineer installing DRL on Lander at the Kennedy Space Center


China Lake and JPL engineers at KSC high-bay assembly facility

Radar Systems. JPL adapted the radar altimeter from a Harpoon missile, and WD engineers built a test vehicle to deploy the radar system from a helicopter that made terrain-approaches over several types of geologic features. Then a series of drop tests was conducted to capture terrain-approach data at realistic speeds. The radar altimeter supplies the descending spacecraft with altitude and velocity data for use in timing airbag deployment and retro-rocket ignition.

Retro-Rocket Systems. WD conducted several motor-burn tests at its Weapons Survivability Laboratory. The flight-spare backshell was suspended from a test tower and restrained by the bridle. The retro-rockets were ignited to determine thrust and structural reactions. Follow-on tests were conducted with other motors to study and compensate for wind, proper separation of environmental covers, and inadvertent torque effects. Retro-rockets slow the Lander down from 200 mph until it hovers above the planet surface, ready for the airbag landing.


Retro-rocket testing at China Lake's Weapons Survivability Laboratory

Multi-Body Tests. Weapons Division tested the system. During descent, the parachute, backshell, and Lander are connected by lines and bridles into a three-body system. JPL was very interested in the dynamics that would result during the descent to Mars. So China Lake's Crew Systems built a simulated three-body test item and dropped it from a helicopter. On-board and ground-based instruments and video captured the response.

Six Minutes Of Terror. Entry, Descent, and Landing (EDL) on Mars requires perfect timing. More than half of all missions to Mars have failed. Landing entails getting a one-ton spacecraft traveling at 12,000 mph to safely stop within six nail-biting minutes. In the first four minutes, atmospheric friction slows the spacecraft to 1,000 mph and raises the temperature of the heat shield to about 2,600°F. With only 100 seconds left, a parachute slows the spacecraft to 200 mph; 20 seconds later, the heat shield is jettisoned, exposing the Lander inside; 10 seconds later, the backshell, still attached to the parachute, begins lowering the Lander on the bridle. A radar system then begins measuring altitude. Eight seconds before touchdown, gas generators inflate the Lander's airbags; two seconds later, the three main deceleration rockets on the backshell ignite, and one or two (of a set of three) small transverse rockets may be fired for stabilization if needed. Three seconds later, when the Lander is about 49 feet above ground, the bridle is cut and the Lander free-falls, cocooned in airbags, hitting the surface at 30 to 50 mph. The Lander then bounces as many as 30 times and rolls up to a mile before stopping. If it hits a sharp rock, the mission could be over—Mars is plagued with jagged boulders, massive craters, cliffs, and high winds.

Perfect Navigation and Control. After traveling more than 300 million miles for seven months, *Spirit* made a perfect landing. "My hat is off to the navigation team because they did a fantastic job of getting us right where we wanted to be," said Dr. Steve Squyres of Cornell University, Ithaca, N.Y., Principal Investigator for the science payload. "This is our new neighborhood. We wanted someplace where the wind had cleared off the rocks for us. What we're seeing is a section of surface that is remarkably devoid of big boulders, at least in our immediate vicinity." Three weeks later, *Opportunity,* an identical twin to *Spirit,* also made a near-perfect landing halfway around the planet from where *Spirit* landed. JPL's Pete Theisinger, project manager for the rovers said, "We are two for two." And Dr. Steve Squyres, proclaimed, "We have scored a 300-million mile interplanetary hole in one." WD tested the rocket motors that helped ensure both of these precision landings. In addition, WD engineers were part of the team that evaluated the landing performance of *Spirit* in preparation for the *Opportunity* landing.

JPL, NASA, Navy, Industry Partners. According to Dr. Charles Elachi, director of NASA's JPL, President George W. Bush called to congratulate the MER flight team for reconfirming the American spirit of exploration, stating that "…We have assembled the best team of young women and men this country can put together." In addition, people from around the world share a special connection to this mission. The Landers each carry a DVD containing millions of names collected during a "Send Your Name to Mars" campaign. Images from this mission have the highest-resolution, more than three times that of the 1997 Mars Pathfinder. Only two weeks after the landing, NASA's Web portal received more than two billion hits, and users downloaded 154 million Web pages worldwide.


Spacecraft separation test at China Lake's MESA facility

Initial activities are also under way for developing a lander dynamics test facility at China Lake in support of JPL's Mars Science Laboratory (MSL) program. The MSL is to be the first of a new generation of smart landers capable of exploring hazardous locations on Mars. The next mission is planned for 2009.


White House Photo Eric Draper

"Congratulations for reconfirming the American spirit of exploration."

—President George W. Bush

Movies/Animation. Additional information is available from JPL at http://marsrovers.jpl.nasa.gov; from Cornell University at http://athena.cornell.edu; and from NASA at http://marsrovers.nasa.gov. Numerous animations clearly illustrate the mission, see: Entry, Descent, and Landing (EDL).[168]


NASA/JPL

SPACE PROJECTS (HISTORICAL)

NASA Support. During 2000, the China Lake Supersonic Naval Ordnance Research Track (SNORT) facility conducted "fly-by" tests propelling a prototype, laser-based hazard avoidance system for use on future Mars smart-landers. In 2000 and 2001, China Lake evaluated technology for a system to anchor a spacecraft to the surface of a comet, evaluated the feasibility of firing prototype canisters into a variety of terrains for a Mars mission, and performed tests on space shuttle bail-out systems. China Lake works with NASA, and other services, on the Integrated High Payoff Rocket Propulsion Technology, the goal of which is to double rocket propulsion performance by 2010. Early projects have included developing a parachute system for the Galileo Atmospheric Probe in the 1980s, testing the parachute for the Space Shuttle solid rocket boosters, designing and evaluating an emergency-escape system for the Space Shuttle, and testing a rocket-assisted deceleration (RAD) system for Pathfinder. China Lake fabricated the RAD-landing package tether system that was used in the successful Pathfinder landing on Mars in 1997. [45]

Satellite/Moon Projects/ Test Track. In the 1960s, China Lake developed, assembled, and tested the Moon Lander 1105R Soft-Landing Vehicle, incorporating an experimental variable-thrust liquid-fuel rocket motor and advanced optical sensors. Although the device didn't make it to the moon, China Lake did develop an optical-contrast seeker that was used on some moon-lander flights to automatically control the engine thrust as it approached the surface. When scientists wanted to simulate earthquakes on the moon, China Lake developed the propellant for a series of mortars that astronauts actually left on the moon. These were later fired remotely from earth to provide "moonquakes " for scientific study. China Lake was the only laboratory that had the propellant technology to meet NASA's rigid requirements. The propellant had to endure the moon's frigid vacuum for seven weeks and still work. China Lake was also used as a test track for the Lunar Rover because of terrain similar to the moon. China Lake was the first to demonstrate a concept for an experimental antisatellite interceptor program and participated in early strategic-defense and space-research projects by developing probes, propulsion systems, and sensors. China Lake's SNORT was used for numerous NASA tests, including tests of the Gemini spacecraft and aircrew safety and ejection systems. China Lake was also the first to develop technology for satellite reconnaissance that allows electronic images to be sent back to earth from space. [46]

NOTSNIK—One of the First U.S. Satellites.

In August 1957, Soviet Premier Nikita Khruschev announced the launching of a long-distance multistage intercontinental ballistic missile. According to Khruschev, the Soviet Union could now "direct missiles into any part of the world," and the Soviets demonstrated their superiority by launching Sputnik, the earth's first manmade satellite. Many American rocket experts predicted that the U.S. was "facing a technological Pearl Harbor." In response to this challenge, China Lake's NOTSNIK team made six attempts to launch a China Lake-designed and -built missile and payload into orbit. Flying over the Sea Range at Point Mugu, the pilot gained as much speed as possible at an altitude of about 40,000 feet, and then pulled up into a steep climb. When he reached an altitude of about 70,000 feet, he launched NOTSNIK. The aircraft was unstable at that altitude and the engine would flame out. Five of these tests clearly failed. However, the failure—or success—of the third orbital try is still a subject of debate. According to Dr. John Nicolaides, former Technical Director of the Navy's Space Program in the Bureau of Ordnance in Washington, D.C., the third NOTSNIK did enter orbit. [47]

Mountaintop Laboratory. In 1948 China Lake built its highest, coldest, and most remote laboratory—a small facility perched near the bleak summit of California's White Mountain. Dr. Ira S. Bowen, California Institute of Technology (Caltech) astronomer and director of the Mount Wilson and Palomar observatories, had been the genius behind much of NOTS' early instrumentation. In 1947 he was looking for a high-altitude observation station so he could study the surface of the sun for magnetic storms, which were known to be indicators of disruptions to electrical communication systems on earth. The construction crew blasted and bulldozed a narrow, tortuous 19-mile road, sometimes following an old wagon trail, up to 12,242 feet elevation. The first two buildings, at elevations of 9,850 and 10,500 feet, opened in 1949. Robert Leighton (also from Caltech) used a cloud chamber at the site to obtain the world's first pictures of V particles. Dr. Robert B. Brode put in a large mass spectrometer, and UCLA's Robert Leonard carried out a year's study of the attenuation of sound waves. [49]

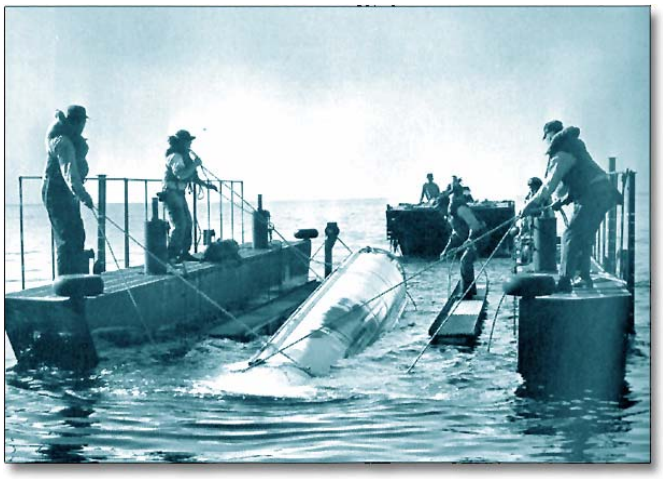
Nobel Prize Winners

Dr. Carl D. Anderson conducted experiments on White Mountain. Anderson was one of two Nobel Prize winners from Caltech who helped establish the early NOTS station. Anderson became a Nobel Laureate in physics for his discovery of the positron. The other Nobel Prize winner, instrumental in establishing NOTS, was William A. Fowler. He directed the early Caltech rocket programs that tested at NOTS. Fowler also conducted studies of the nuclear reactions in the formation of the chemical elements in stars.) [49]

Since those days, this facility has been used for a variety of high-altitude testing, including Long Jump, a WD program that obtained infrared signatures of aircraft from a ground-based test station (aircraft could fly toward the station from more than 50 miles away while remaining below the station's altitude). Long Jump tests were conducted in 1985, 1986, 1988, and 1990 at the Barcroft Laboratory at 12,470 feet. In Long Jump IV, 36 different sensors were tested and evaluated. Barcroft Laboratory is now part of UCLA. [48]

High-Flying Research. In 1946, NOTS supported high-flying research. During the nearly four years that B-29s were stationed at Armitage Field, they flew 268 missions for an estimated 600,000 miles at altitudes up to 40,000 feet. These flights accumulated data to support research conducted by physicists all over the country. The participating scientists authored an extensive collection of scientific publications, and NOTS received widespread recognition in the scientific community for its part in the program. [49]

Point Mugu Space Support. In the late 1950s space-related activities at Point Mugu supported the Navy as well as the Army, Air Force, NASA, Advanced Research Projects Agency (ARPA), and Atomic Energy Commission (AEC). Support involved instrumentation at a number of down-range sites on the islands of Oahu, Kauai, Wake, Johnston, Canton, and Kwajalein. Also, the range had at its disposal four range ships equipped with instrumentation and two WV-2 aircraft for telemetry data collection. Two of the ships could monitor the re-entry of space capsules and recover them at sea. Support for the Air Force was provided primarily in the launch of the Discoverer series of satellites from Vandenberg AFB, the monitoring of orbiting satellites, and the recovery of space capsules.



Point Mugu was very involved in the planning support for NASA during Project Mercury, the nation's first manned orbiting space capsule. Point Mugu also conducted drop tests on the Nuclear Emulsion Recovery Vehicle (NERV) being developed by ARPA for NASA (six launches were assigned). ARPA also assigned projects to Point Mugu, including SARV (Mk IV) Air Force nose cone drop tests; instrumentation support for the Air Force manned boost-glide spacecraft DYNA-SOAR project; and work on TEEPEE, a Navy program for detecting ICBM launches and nuclear explosions by backscatter. AEC programs involving Point Mugu centered on the construction of a launch facility to be used in Project Tumbleweed, the first launch of which occurred in 1960. Support of Missile Defense Agency and Air Force ballistic launch programs have continued, primarily with the NP-3D airborne telemetry, command destruct, and photo optical systems. The NP-3D telemetry systems have been used extensively in support of NASA space launch programs, including support for placing numerous satellites in orbit and support of Mars space probes. [50]

Life Science. During the 1960s and 1970s, Point Mugu investigated a variety of medical, biological, and psychological factors relating to aeronautic and astronautic activities. One project helped to establish design specifications for the flight cabins of manned space vehicles. Extensive studies evaluated the effects of atmosphere, oxygen, and pressurization. For example, human subjects were exposed to a simulated 34,000-foot-altitude for five days in order to test pressure suits. In addition, Point Mugu studied bio-acoustics to determine the effects of noise on humans. A staff of engineering psychologists examined the effects of high-energy acoustic levels involving aircraft, missiles, and impulse noise associated with Naval weapons. Many safety changes were made as a result of these studies. [50]

Navy Astronautics Group. The Navy Astronautics Group, with headquarters at Point Mugu, was commissioned in 1962 to operate the Navy Navigational Satellite System (NNSS), known as TRANSIT, that permitted Fleet units to fix their precise positions at sea, day or night, in any kind of weather.

In 1963, the destroyer *USS Hazelwood* was the first Navy vessel to test a then-secret navigation system that received data from an orbiting satellite. Shortly thereafter, the system was made operational for use with the Polaris ballistic missile submarines and aircraft carriers.

In 1967, the government authorized manufacture of commercial versions of the shipboard navigation sets and sale to non-military interests. Applications included oil exploration, mapmaking, worldwide commercial shipping, and as a universal time standard. System accuracy was emphasized during rendezvous and recovery operations in connection with astronauts returning from Apollo expeditions to the moon. The navigation satellites were launched into 600-mile circular polar orbits from Vandenberg AFB. They orbit the Earth every 107 minutes, transmitting a message every two minutes describing where they were in space. The Navy had tracking and injection stations in Maine, Minnesota, on Laguna Peak at Point Mugu, and in Hawaii. Point Mugu managed the entire system. TRANSIT operations continued until 1996 when the new GPS technology became operational. In 1990, the original astronautics group was formally redesignated the Naval Satellite Operations Center (NAVSOC), under the guidance of the Naval Network and Space Operations Command. Today, NAVSOC maintains the six remaining TRANSIT satellites, but they have also greatly expanded their mission and operations to include multiple satellite operations, and they now have additional detachments in Guam, and Colorado. [51]

UNDERSEA PROJECTS (HISTORICAL)

Undersea projects include a variety of weapons, systems, and technologies that are associated with undersea warfare. In the 1940s, the Bureau of Ordnance (BuOrd) selected China Lake/NOTS, with its facilities at Inyokern and Pasadena, to conduct torpedo and other undersea projects. BuOrd decision-makers believed that the Station had the requisite expertise in both rocketry and underwater ordnance.

The Morris Dam facility, at China Lake's Pasadena Annex, helped designers develop new weapons for underwater operations. Using the Fixed-Angle Launcher, full-scale torpedoes could be launched under controlled conditions. The

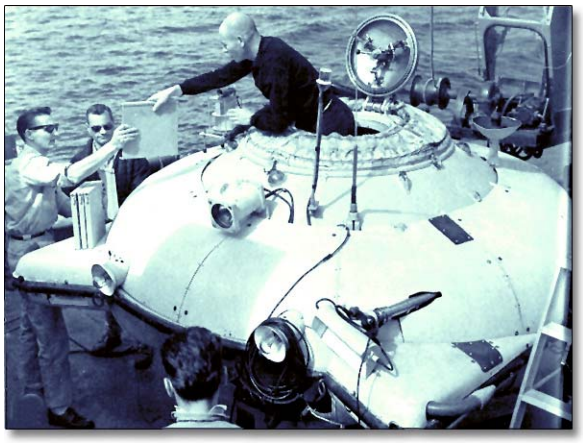
steeply rising mountains that surrounded the lake behind the dam provided excellent camera sites. A torpedo shop, test pits, and an underwater cableway were also constructed, and the ingenious Variable-Angle Launcher (VAL) was dedicated in 1948. VAL was a steel bridge, 22 feet wide, 35 feet high, and 300 feet long, that supported two launching tubes from which torpedoes could be launched at various angles and at velocities of up to 1,000 feet per second. Beginning in 1946, China Lake/NOTS developed Weapon A, a 12.75-inch rocket-propelled depth charge for use against submarines. Weapon A remained in the Fleet inventory for 18 years until it was replaced by another China Lake/NOTS product—the Antisubmarine Rocket (ASROC).

Other successful projects included the Mk 46 torpedo, a deep-diving, high-speed antisubmarine torpedo. If the first pass was not successful, the torpedo was capable of starting a helical search pattern for multiple re-attacks. The Mk 46 Mod 0 entered service in 1963, and the Mod 5A(SW) went to the Fleet in 1996. More than 1,000 Mk 46s still remain in U.S. service. Variants are used by approximately 30 countries. China Lake's Underwater Ordnance Department based at the NOTS Pasadena Annex, also developed the Rocket Assisted Torpedo (RAT); Deep Jeep, the first U.S. manned submersible to descend more than 2,000 feet; ASROC; and the cable-controlled underwater recovery vehicle (CURV), a deep-water diving vehicle for recovering torpedoes. It was used to recover a nuclear weapon in deep water off the coast of Spain.

Also developed at China Lake was Moray, a two-man deep-diving test vehicle to explore concepts for small fighter submarines.

During Vietnam, China Lake conducted the Special Warfare Program (Swimmer) that carried out quick-response efforts supporting underwater demolition teams. A large array of specialized devices was developed, including the Actuation Mine Simulator (AMS) for training and minesweeping.

Torpedo component research and modification were emphasized after Vietnam, and studies in controls, structures, ballistics, and propulsion systems improved torpedo technology. New fabrication methods, head shapes, and propulsion fuels were created. Of particular note were two torpedo propulsion systems—one a pumpjet type and the other a hydroturbojet type—developed at China Lake and the Mk 40 and Mk 41 torpedoes. Work 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. [46]



Marine Biology. China Lake was talking to dolphins and studying the way fish swim in the early 1960s. Project "Notty" originated at China Lake in 1962 and was tested at Point Mugu. Tanks were built near the entrance of the Mugu Lagoon, where the animals were trained for such high-risk tasks as deep-water recovery and explosives placement. Studies were conducted involving sonar, tracking, and hydrodynamics. Project "Notty" generated further interest in investigating dolphin capabilities, including trainability, intelligence, and communication. Unlike human divers, dolphins and sea lions can make repeated dives to depths of hundreds of feet, have excellent directional hearing, and are not hindered by currents or reduced visibility. Dolphins also possess an excellent sonar system capable of fine discrimination of materials and shapes. It became clear that marine mammals could perform tasks that are difficult or hazardous for human divers.

At Point Mugu, an aquatic test facility was constructed, and filtered seawater pools and tanks were built with a comprehensive array of high-frequency sonar equipment, hydrophones, speakers, and recorders. The project was staffed with marine zoologists, trainers, veterinarians, and sonar experts. The Navy was studying dolphins, Orcas, seals, and sea lions. Dolphins were known to be friendly, intelligent animals that could assist in underwater operations if given proper training. As many as a dozen dolphins were used, and all animals had the best medical care—weekly physical examinations.

In a Sea Lab II experiment, aquanauts lived 200 feet below the surface for 30 days. During this time, Tuffy, a 270-pound bottlenose dolphin, carried tools down to them and brought back mail to the surface. He also had rescue duty training. By sounding a buzzer, a lost aquanaut could call Tuffy to dive down with a safety line. The dolphin never failed in drills. Over a period of eight years, numerous sonar-related experiments generated a vast library of tape-recorded dolphin noises that scientists used to develop new approaches for sonar equipment. [50, 136]

Barking Sands Tactical Underwater Range (BARSTUR). This unique underwater range provided the Pacific Fleet Operating Forces with anti-submarine tactical launching and training capabilities, including exercises that involved submarines, surface vessels, aircraft, torpedoes, and targets.

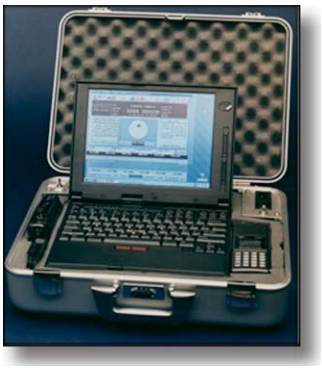
The original underwater tracking network covered a 5- by 10-mile area to water depths ranging from 2,400 to 6,000 feet. Shore-based facilities at Barking Sands, and a remote radar site for surveillance and tracking of air and surface objects located at Makaha Ridge, supported the underwater range. Installation began in 1966. In 1968, the first full year of operation, approximately 800 hours were devoted to Fleet operations such as sonar anti-submarine warfare (ASW) torpedo attack exercises. In 1973, the Barking Sands Underwater Range Expansion (BSURE) project expanded the original range to 1,000 square miles. Engineers laid two 65-mile-long cables, and spaced 16 hydrophones on each cable string. Electronic housings were built to withstand extreme pressures, and a water-tight enclosure or pressure vessel protected sensitive electronics at depths as great as 16,000 feet. In-water hardware was manufactured using many space technology techniques.

In 1993 PMRF transitioned to the Fleet and is currently under the command of COMPACFLT Pearl Harbor, HI. In 1998, PMRF's Shallow Water Tracking Range (SWTR) was created when an additional 125 square miles of seafloor were instrumented and 120 hydrophones installed. SWTR is the only shallow water tracking range in the world, allowing PMRF continuous underwater track more than 1,200 square miles, from water depths of 120 to more than 16,000 feet. In 2003, more than 1,300 hours of T&E and training operations were conducted, including large Fleet exercises (HOLLYWOOD, RIMPAC) and T&E exercises (marine mammal tracking tests, acoustic telemetry testing, virtual torpedo development, and other basic acoustic research from University and Navy lab customers). The underwater range at PMRF-combined with PMRF's surface and airborne range tracking, communication, telemetry systems, and near zero range encroachment north of Kauai-make PMRF the pre-eminent range in the world. [50]

RAPID PROTOTYPING FOR QUICK-FIX FLEET SOLUTIONS

The Fleet Support Initiative (FSI) is an effort to identify small, quick-fix problems at the working level in the Fleet and to find a solution. Another key function is to build NAVAIR participation in the Office of Naval Research (ONR) Tech Solutions process, established to receive and respond to Fleet requests. The concept is to focus and communicate actively with Sailors and Marines to determine what went wrong on their last deployment and what future capabilities are needed.

One of the goals is to identify and select tasks that can be accomplished in a year or less. Among the FSI projects are efforts to provide a low-cost "Link-16" for legacy platforms, a thermal-imaging maritime surveillance system, a small, lightweight night-vision device for aircrew survival vests, and a night-vision goggle-compatible flashlight. Several of these simple, inexpensive solutions can make the difference in whether or not an aircraft or the lives of aircrew survive an emergency. Tech Solution requests for support, include improved helo ballistic protection, line-of-sight communications, covert ejection seat beacons, and portable solar panels.



Since the Vietnam War, China Lake and Point Mugu have participated in the Vietnam Laboratory Assistance Program (VLAP) and the subsequent Navy Science Assistance Program (NSAP), providing quick, low-cost, solutions to important Fleet problems throughout the world. NSAP is now the ONR Naval Fleet Force Technology Innovation Office.

WD Fleet Weapon Support Teams (FWSTs) also provide on-site technical and training assistance to operational forces worldwide. For the war on terrorism, WD has outfitted unmanned aerial vehicles (UAVs) with specialized sensors and instrumentation required for Coast Guard and Homeland Defense missions. WD has accelerated periscope radar development to increase submarine safety in littoral waters, and is developing special tunnel-warfare weapons and technology, as well as Spike, a low-cost guided missile that fits neatly in a Marine and Navy Seal commando backpack.

WD has historically provided customized direct support for special warfare systems. Examples include nonirritating face paint sticks, night-vision devices, map illuminators, liquid explosives, small personal identification beacons, hand-emplaced fuel-air explosion (FAE) canisters for mine clearance, lightweight gun pods, a lead-computing gun sight for aircraft, luminous wristwatch dials, auto-inflatable life preservers, 20-mm gun pods, and the Limpet Assembly Modular (LAM) swimmer-emplaced mine.

WD also provides direct support to the Special Operations Forces with custom explosives, grenades, specialized weapons, communications gear, air and ground reconnaissance technology, thin-pack parachutes, portable targeting systems, and other unique support equipment. [52]

NAVAIR WD IN THE NEWS

This section contains edited summaries from newspapers, magazine articles, interviews, briefings, and reports.

- Material is organized by conflict starting with Operation Iraqi Freedom and going back to World War II.
- Within each conflict, entries are categorized by the types of work performed at the Weapons Division.

Weapons/Weapon Systems	Modeling and Simulation
Weapon Platform Integration	Research, Science, and Technology
Interoperability/Battlespace Integration	Direct Fleet Support
Test and Evaluation and Range Support	Crew Systems
Electronic Warfare	Homeland Defense
Energetics	Special Weapons/Projects
Survivability/Vulnerability/Lethality	General

- Many entries are examples of direct use in a specific conflict. Other entries reflect accomplishments during that period, but are not directly tied to the conflict.

OPERATION IRAQI FREEDOM (2003–Present)

Weapons and Weapon Systems

WD supported the integration and development of more than 80% of the weapons used in theater during Operation Iraqi Freedom. Weapons included JSOW, JDAM, HARM, Tomahawk, SLAM-ER, LGB/GBUs, and AMRAAM.

Antiradar Missile Scores Hit

As part of its continued effort to destroy an adversary's air defenses even after they shut down, the U.S. Navy last month conducted another test of its Quick Bolt HARM upgrade. The initiative involved the addition of a dual-mode seeker to the antiradar weapon, as well as the ability to provide cues to the missile from intelligence satellites. QB-2, the latest test, was conducted at the Navy's China Lake weapons range. The missile homed on the target using the combined passive antiradiation and active millimeter-wave seeker. The radar was turned off after the missile was launched. Moreover, the weapon employed an impact-assessment feature to transmit its status just before striking the target, which should aid in battle damage assessment. The two Quick Bolt tests, which focus on the receipt of off-board information, follow five stand-alone trials of the dual-mode Advanced Antiradiation Guided Missile (AARGM) seeker. [53]

ATFLIR—Advanced Targeting for the Fleet

It's newly introduced to the Fleet, it provides powerful imagery, and it performs. The Advanced Targeting Forward-Looking Infrared (ATFLIR) is delivering real-time passive thermal imagery, day or night, to the Super Hornet pilot. And the Fleet likes what it sees. "ATFLIR will make the F/A-18 once again the Navy's premier precision strike platform, with the best targeting system in the world," said ATFLIR Project Officer and F/A-18 Flight Test Officer LCDR Dave "Scoop" Swenson. "ATFLIR provides more than three times the magnification of the LANTIRN flown on the F-14," added Swenson. A government and industry team of the NAVAIR China Lake Advanced Weapons Laboratory, Boeing, and Raytheon delivered the goods. Swenson talked about what he considers ATFLIR's biggest accomplishment; "it was the early operational capability we gave the Fleet in support of the War on Terrorism. The Eagles of VFA-115 took three pre-production pods on cruise with *USS Abraham Lincoln* (CVN-72), and ATFLIR was used as a reconnaissance sensor in support of Operations Enduring Freedom, Southern Watch, and Iraqi Freedom." Along with VFA 115's deployment, in March of this year, the Black Aces of VFA-41 took three production pods on cruise with *USS Nimitz*, and employed ATFLIR in the FAC(A) and Close Air Support roles as an air-to-ground targeting sensor in support of Operation Iraqi Freedom. Raytheon serves as the prime contractor for ATFLIR. [54]

JDAM

6,500 Dropped. Navy and Marine Corps carrier-based aircraft flew nearly 8,000 missions in the first three weeks of the Operation. F-14, F/A-18 (the F/A-18E Super Hornet in its maiden combat deployment), and AV-8 aircraft dropped more than 6,000 precision-guided weapons—including 2,400 JDAMs—during battlefield interdiction missions, strikes against command and control targets, and close air support operations. Overall, 6,500 JDAMs were dropped and over 800 Tomahawk cruise missiles were launched. [55]

Navy's F-14D Fleet is Now Mk 84 JDAM Capable. The test and release of the F-14D Operational Flight Program (OFP) D04 software was accelerated and then deployed to all F-14D squadrons. This effort spread across three aircraft carriers, with the team completing a transatlantic crossing to upgrade VF-213 on *USS Roosevelt* and simultaneously completing upgrades to VF-31 and VF-2 on station in the Persian Gulf aboard *USS Lincoln* and *USS Constellation*. Software updates also added high resolution mapping (HRM), GBU-24E/B full-interface mode, Military Grid Reference System (MGRS), and Joint Tactical Information Distribution System (JTIDS) enhancements. All F-14Ds are now carrying JDAM! [55]

Joint Unmanned Combat Air System (J-UCAS)

The Joint Unmanned Combat Air System (J-UCAS) will provide autonomous surveillance; suppression of enemy air defenses; and strike capability for the Air Force and Navy. WD participated in the program from its earliest stages and will continue to provide support through and beyond Initial Operational Capability in 2008. WD is the Navy's technical lead for the current J-UCAS program in software, sensors, weapons integration, cost analysis, effectiveness analysis, and test and evaluation. Northrop Grumman's X-47A Pegasus was brought to China Lake for all taxi and flight tests in 2002 and 2003, and the very first flight of an "X Plane" at China Lake was conducted on February 23, 2003, with WD providing test and evaluation engineering, operations, and range support. Boeing's X-45A Unmanned Combat Air Vehicle is also scheduled to conduct weapon drops on the WD ranges. UAV weaponization is another growing area of DOD interest.

Predator/Hellfire integration and separation testing were conducted on WD's ranges in late 2001, just prior to the successful use of Hellfire from a Predator during the war on terrorism in Afghanistan. Predator/Stinger tests have also been carried out on WD ranges. The OSD-sponsored Joint UAV Joint Test and Evaluation (JT&E) Program, led by the Navy at Fallon, Nevada, is developing joint tactics, techniques, and procedures in time-sensitive operations. WD is the modeling and simulation lead for this effort. WD's Integrated Battlespace Arena (IBAR) has successfully modeled numerous architectures integrating UAVs into the battlespace. Lessons learned from Operation Iraqi Freedom are being implemented through JUAV. Virtual rehearsals are conducted in simulation prior to all live exercises. [56]

F-14D

NAVAIR's F-14D Team deployed JDAM capability on three carriers in two oceans in three weeks. To give the F-14D Tomcat fighter a larger role in the impending war in Iraq, the Navy rushed a newly developed Operational Flight Program (OFP) D04 to all F-14Ds in the war zone, enabling them to drop the most devastating satellite-guided bunker buster bombs on target. All 30 F-14D fighters aboard the aircraft carriers *USS Theodore Roosevelt*, *USS Abraham Lincoln,* and *USS Constellation* were modified approximately six months ahead of schedule to carry the DO4 after accelerated testing of DO4 was deemed low risk by COMOPTEVFOR (Commander, Operational Test and Evaluation Force). On February 2, 2003, the Navy transported an upgrade support team of F-14D IPT personnel to *USS Roosevelt* to make the required changes to aircraft, and software. The team formed two sub-teams to accomplish the accelerated schedule concurrently on *USS Lincoln* and *USS Constellation*. The upgrades to all forward-deployed F-14Ds and the training of 90 aircrew and numerous maintenance personnel were completed within 17 days. A Navy's F-14D from *USS Constellation* provided the first operational JDAM strike on March 1, 2003, when it destroyed a ground target over Iraq in support of Operation Southern Watch. The Navy's F-14D with JDAMs were used extensively with pinpoint accuracy to eliminate high-priority targets in Operation Iraqi Freedom. [57]

F-14D/JDAM Integration Completes Accelerated Deployment

NAVAIR's F-14D Team Deploys JDAM Capability On Three Carriers In Two Oceans In Three Weeks. With more than 350 laboratory test hours and more than 270 flight hours on an OFP, the Weapon System Support Activity (WSSA) provided the Fleet with a capability that keeps the F-14 in the game. According to the VF-213 training officer, "The installation of D04 has allowed the F-14D fleet to double their strike fighter capabilities. The test and development community has done an excellent job, providing the Fleet with the capability it needs at one of the most crucial times in our nation's history." The WSSA is working on the final block upgrades for the F-14B and F-14D, scheduled to be with the Fleet in 2004. Point Mugu carried out the F-14 transformation from a premier fighter to a world-class fighter/precision strike/reconnaissance aircraft. According to a team member, "We provided three forward deployed F-14D squadrons on three different aircraft carriers with one of the finest weapon systems ever developed. Thirty aircraft were modified in just three weeks. This achievement was possible due to the first-rate support provided by each squadron and various NAVAIR and AIRLANT activities. This teaming of the Fleet with NAVAIR and the Weapons School was epic, with all parties pulling together for the ultimate goal." [55]

Weapons Division Supports Weapons That Work. The enemy forces are lobbing mortar at coalition special forces in northern Iraq. Suddenly, the radio crackles inside an F/A-18 Hornet, deployed aboard *USS Theodore Roosevelt*. The call, whispered to prevent detection, has coordinates and a few nearby landmarks easily seen from the air. "I dropped the ordnance and the next thing I heard from the ground was 'Sweet!'" said a pilot with CVW-8 staff. "We're providing that kind of coverage." Scenarios like this happen almost daily during the strikes over Iraq, and it demonstrates the accuracy with which precision-guided ordnance can hit a target. "Dropping JDAMs and laser-guided ordnance is one of the most satisfying missions for our pilots," said the commander, CVW-8. "They are told where to drop the munitions, and they get direct feedback from the troops after they're dropped." [58]

Hellfire

New MAC Warhead. In support of Operation Iraqi Freedom, WD designed, developed, and built a new metal augmented charge warhead that inflicted great damage to multi-room structures during the war. The effects of the warhead are formidable.

> "-- can take out the first floor of a building without damaging the floors above, and is capable of reaching around corners, into niches and behind walls to strike enemy forces hiding in caves, bunkers and hardened multi-room complexes. It went from development to deployment in less than a year."
>
> —Donald Rumsfeld, Secretary of Defense
> Speaking on the AGM-114N Metal Augmented Charge Hellfire

> "The weapons were employed the first night of [the war] with great success." Sewell also quoted the Marine Corps aviator who was the first to use the new Hellfire warhead in combat. '"That thing was awesome,' the Marine said. 'I thought it was a 2,000-pound JDAM going off.'"
>
> —LCDR Donald Sewell, Pentagon spokesman
> As reported in *Defense Week*

The new MAC warhead technology has its roots at China Lake where, as early as the 1960s, Navy scientists were conducting basic research into fuel-air explosives (FAEs). Concepts were turned into tactical weapons: surface-launched FAE (SLU-FAE) and the CBU-55/72 FAE family. In the 1990s, WD developed nonliquid FAEs containing aluminum particles. The goal was a solid FAE with a greater impulse

(pressure over time) than conventional explosives. Their work received a classified U.S. Patent and was the basis for the MAC warhead. Unlike conventional warheads, which have a sharp pressure spike that decays rapidly, the MAC has a sustained pressure wave. "Thirteen months from funding to fielding," noted the project's systems engineer. "That was total design, development, assembly, explosive loading, integration into the missile armament section, and testing. Normally, that would be about a three-year project." [54]

Hellfire Packs a Greater Punch

Marine assault units engaged in Operation Iraqi Freedom are using Hellfire missiles equipped with a new metal-augmented-charge (MAC) warhead. The new warhead—designed, developed and built at China Lake, with support from the Marine Corps, White Sands Missile Range, Eglin Air Force Base Open Air Range, NAVSEA Indian Head, and Redstone Technical Test Center—inflicts greater damage in multi-room structures than the AGM-114M Hellfire warhead. The effects of the Hellfire MAC warhead are formidable. Unlike conventional warheads, which have a sharp pressure spike that decays rapidly, the MAC has a sustained pressure wave. That pressure propagates throughout a structure to extend the lethal effects of the warhead detonation. In 2002, the Defense Threat Reduction Agency (DTRA) tasked NAVAIR to develop a new Hellfire warhead. That hard work paid off in Operation Iraqi Freedom. [54]

Manufacturing Automation Yields Cost Savings for JSOW

One of the successes of NAVAIR's Manufacturing Technology (MANTECH) Program involves a tiny gyro that weighs less than three pounds and can be held in the palm of your hand. Manufacturing automation of the monolithic ring laser gyro (MRLG) was started in 2000 and completed last spring. The MRLG is the costliest and most critical component of an inertial measurement unit (IMU). The gyro is used on the Joint Standoff Weapon (JSOW), Global Hawk navigator, Fire Scout navigator, P-3 synthetic aperture radar antenna, P-3C antisurface warfare improvement program standard heading reference system replacement, surveillance towed array sensor system gyro compass, and the advanced amphibious assault vehicle navigator. Kearfott Guidance and Navigation Corporation, is responsible for the MRLG success achieved last year. According to Dr. Stan Rajtora, JSOW systems engineer in the NAVAIR Weapons/Targets Department, "Kearfott came to us with a number of ideas to make this even more affordable." The ultimate cost savings were $641 per unit. With an expected JSOW/A production run of 12,000, the Navy and Air Force could save more than $7 million on a MANTECH investment of $1 million. "That's what the MANTECH program does for NAVAIR," said Rajtora. "It funds additional automation of processes so we can eliminate the touch labor, as well as make the process more repeatable. When you make processes more repeatable, you typically improve your performance a little bit, and in the end, increase the yield." [54]

Precision Strike Navigator

Precision guided weapons were effectively demonstrated during Iraqi Freedom. Such weapons can strike high-value targets with a high degree of confidence and minimal collateral damage. WD is developing the Precision Strike Navigator (PSN), which is a fiber-optic gyro (FOG) based advanced inertial guidance system. PSN maintains global positioning system (GPS) accuracy even in the presence of anticipated near-target GPS jamming. Emphasis is on drastic reduction of inertial system size and cost while maintaining desired on-target accuracy. The FOG has rapidly gained acceptance as the inertial sensor technology of the future. The FOG is a lightweight, low-power, and high-reliability alternative to ring-laser and spinning-mass gyroscopes. At the heart of PSN is a unique wafer that replaces all the current handcrafted FOG functions. PSN components are readily mass-produced by proven semiconductor-processing machinery. Dramatic unit-cost reduction is made while maintaining the highest possible performance. [59]

SLAM-ER Scores Direct Hit, Several Firsts, in Time-Sensitive-Strike Demo

A training exercise by Carrier Air Wing One (CVW-1) showed the effectiveness of the Standoff Land-Attack Missile–Expanded Response (SLAM-ER) against rapidly relocatable targets, particularly when employed as part of a networked rapid-targeting team. In this exercise, an airborne Fleet F/A-18C and two S-3Bs received in-flight targeting information. The F/A-18C flew to standoff range and launched the SLAM-ER, and a Fleet S-3B assumed terminal control. The result: a one-shot target kill on NAVAIR's San Nicolas Island. More than 400 miles from Fallon, an S-3B approached the launch point. The pilot selected the SLAM-ER's Target of Opportunity mode and entered targeting information he had received from the Tactical Dissemination module (TDM). At 30,000 feet and more than 50 nautical miles from San Nicolas Island, they launched the SLAM-ER. As the missile flew toward San Nicolas Island, the Viking crews watched live video from the SLAM-ER's seeker, transmitted by the missile's Advanced Weapon Datalink. When the missile was 15 nautical miles from the island, the primary Viking crew assumed control, guiding the missile via the AWW-13 pod using the SLAM-ER's Stop Motion Aimpoint Update (SMAU) feature. SMAU allows the weapon controller to momentarily freeze the target video image on the display screen. A direct hit, smack in the middle. [54]

Tomahawk

Tactical Tomahawk Stretches Its Legs. History was made as the U.S. Navy's new Tomahawk cruise missile, Tactical Tomahawk, was launched from an Arleigh Burke Class Destroyer, *USS Stethem* (DDG-63), on NAVAIR's sea test range off the coast of southern California. This first launch of the Block IV Tactical Tomahawk from an operational surface ship equipped with the Tactical Weapon Control System marked the beginning of the final phase of government evaluation testing. The missile will become operational in the

middle of 2004. This test successfully demonstrated the newest advances in the Tomahawk Weapon System communication suite by validating transmissions, reception and initiation of the missile prior to launch. Demonstrating its unique communication capability, the missile established a satellite link with its launch platform and passed numerous tactical messages to demonstrate its real-time command and control communication capability. The missile continued swiftly through its 780-mile test flight, using GPS updates to successfully navigate to the target impact site. [54]

Tactical Tomahawk Presses on with Its First Live Warhead Test From Sea Range. The U.S. Navy's new Tomahawk cruise missile, Block IV or Tactical Tomahawk, was launched May 8, 2003, from an Arleigh Burke class destroyer, *USS Stethem* (DDG-63), in the waters of the NAVAIR sea test range off the coast of southern California. This event marked the second launch of the Tactical Tomahawk from an operational surface ship and the first live warhead demonstration. When asked to comment on test activities, CDR David Melin, commanding officer for *Stethem* said, "I am extremely proud of *Stethem's* contributions to the Tactical Tomahawk program. Every shot is a significant program milestone that gets us one step closer to fielding this next generation force multiplier for the Navy's land attack warfare mission. The efforts of the 340 'steelworkers' of *Stethem's* program offices, land-based test sites, and contractors are paying huge dividends as evidenced by this second flawless launch from *Stethem* and fifth perfect flight of the Block IV missile." [54]

Weapon Platform Integration

Digital Precision Strike Suite (DPSS)

DPSS provides a brand-new capability for the Fleet. It is a self-contained laptop system that increases the success for first-pass attacks with smart weapons. The computer correlates real-time target images from various sensors with existing geographical database imagery and assigns a latitude, longitude, and elevation to any part of the target. These targeting data are then transmitted to the aircraft and weapon. This is all done in less than a minute by one operator, using a laptop computer. Already tested in operations in the field, DPSS revolutionizes strike warfare. [55]

F/A-18 Shared Reconnaissance Pod Developed by NAVAIR Team and Scheduled for Early Deployment

"The Fleet is going to love it," shouted an enthusiastic pilot who was describing SHARP, the Shared Reconnaissance Pod. SHARP, developed by NAVAIR to provide a reconnaissance capability for the F/A-18E/F Super Hornet, was approved for early deployment. Through a tremendous effort on the part of the SHARP's test team, the Fleet will be able to put the Pod's imaging capability to good use, only three months after SHARP's first flight. The Advanced Weapons Laboratory's (AWL's) project lead, praised the team, referring to their Herculean efforts to get this capability to the Fleet. During its first flight, SHARP collected visible and infrared wavelength imagery from station six of a Super Hornet for two hours as the aircraft flew over the ranges at China Lake. According to developers, SHARP will be more reliable, day/night capable, with a near-real-time data link capability and near-instantaneous image processing. NAVAIR's AWL led the software development and integration, which will allow SHARP to function while installed on the F/A-18. [55]

Next Generation AESA Radar Takes First Flight in an F/A-18 Super Hornet

The first flight of the integrated APG-79 Active Electronically Scanned Array (AESA) Radar was flown in a U.S. Navy F/A-18 Super Hornet at NAVAIR China Lake on Wednesday, July 30, 2003. The flight marked another milestone in the spiral development of the aircraft by commencing an extensive flight test program with the APG-79 installed. The new radar will make the F/A-18 an even more powerful precision strike platform providing revolutionary capability to the Fleet. "We are continually increasing the capabilities that puts the "super" in Super Hornet" said NAVAIR F/A-18 Program Manager CAPT B. D. Gaddis. The AESA radar system is integrated in the F/A-18 by the prime contractor, The Boeing Company of St. Louis, and built under a subcontract by Raytheon Corporation of El Segundo. The integrated NAVAIR and industry team expects to deliver the radar to the Fleet by 2006. Performance and capabilities of current airborne radars are limited by the speed of the mechanically scanned antennas. In an active-array radar like the APG-79, the radar beam can be steered at close to the speed of light. This rapid beam scan feature enables superior performance and capabilities. The APG-79 radar's Multi-Function Array is comprised of numerous solid-state transmit and receive modules, or T/R modules. The APG-79 is more lethal, more survivable, more reliable, and more affordable than its mechanical cousins. [54]

Tactical Dissemination Module (TDM)

China Lake invented and developed the Tactical Dissemination Module (TDM), a revolutionary new portable computer/radio system that creates customized real-time-targeting strike packages for specific aircraft. For example, a special operations force identifies a time-critical target. Next, they digitally photograph the target, determine the approximate GPS coordinates, and then transmit the data back to Central Command (CENTCOM), who decides which weapon is currently available (target weapon pairing), in order to make the call for fire (CFF). When TDM receives the CFF over a secure network, the target-package generator automatically fills in the fields on a computerized worksheet and then automatically formats the information into a standard nine-line message specific to the launch aircraft. Reconnaissance images, as well as pre-existing satellite imagery, are chipped (re-sized and oriented for pilot ease of use). In addition, the location of friendly forces or enemy surface-to-air threats is identified. These funnel-feature navigation aids are used to

lead the aircraft and weapon to the target; sequential images get progressively larger in scale as the target approaches. This package is sent through a secure network to the Forward Dissemination Element, portable computer/radio field equipment), then is transmitted directly into the cockpit of the strike aircraft by means of one of numerous RF data links. In conflict, the rules of engagement require positive target identification before weapon release. TDM delivers this capability. TDM work began at China Lake in 1993, and the Navy's first system was demonstrated in 1994. Through the 1990s, development efforts were part of the Rapid Precision Targeting System (RPTS) project. RPTS was deployed in NATO Bosnia/Kosovo operations. In late 2002, RPTS—now called TDM—was deployed to the Persian Gulf during Operation Southern Watch. Later, during Operation Iraqi Freedom, as coalition forces captured Baghdad International Airport, the FDE was immediately relocated there for the duration of the conflict. TDM supplied more than 900 target packages to coalition bombers and is still forward-deployed. TDM is scheduled to be installed on six U.S. Navy ships in FY04. Using satellite and relay aircraft, designers will extend TDM range from the current 180-mile limitation to virtually anywhere in the world. [60]

Upgrade to 'Bombcat,' Navy Earns Hill Plaudits

To give the venerable F-14 Tomcat fighter jet a bigger role in the war against Iraq, NAVAIR rushed a newly developed software upgrade to all 30 "D model" aircraft in the war zone, enabling them to drop the most devastating, satellite-guided, bunker buster bombs on targets in Iraq last week. This effort quickly drew praise from aides to House Armed Services Chairman Hunter and other lawmakers. All 30 F-14D fighters participating in the war were modified five to six months ahead of schedule after accelerated testing of a software upgrade, said Denise Deon, a NAVAIR spokeswoman. Upgrades and training of 90 aircrew and maintenance personnel were completed within 17 days. JDAMs and cruise missiles have been the primary weapons in the so-called "shock and awe" campaign against fixed targets in Baghdad, Basra, and elsewhere in Iraq. A Navy F-14D from *USS Constellation* gave the upgrade its first "operational" test on March 1 when it destroyed a ground target while patrolling the southern no-fly zone over Iraq. The F-14, featured in the hit movie "Top Gun" with its distinctive twin engines, supersonic speed, and variable sweep wings, entered the Navy fleet in 1973. The most advanced model, the F-14D, was last delivered in May 1992 and is expected to be replaced by F/A-18E and F Super Hornets in about five years. [61]

Test and Evaluation/Range Support

Cookoff Research Receives International Recognition

At the 34th International Annual Conference of the Institute of Chemistry Technology in Karlsruhe, Germany, held June 24 to 27, 2003, Alice Atwood and Pat Curran presented a paper entitled, "The Effect of Initial Porosity on Cookoff Reaction Violence." K. B. Lee, of the Agency for Defense Development, was also a co-author. Atwood, a physical scientist in the China Lake Combustion Research Branch, and Curran, an engineering technician in the Branch, have spent three years studying the effects of thermal damage on the violence of reactions that can occur in a cookoff fire. "To do that, we changed the porosity of the material," Atwood said. "The U.S. Navy has a big interest in the hazard known as cookoff because shipboard fires are extremely costly in lives and in financial damage." An obstacle to modeling and in predicting slow cookoff is the inability to predict the level of violence when the munitions detonate. Atwood, Curran, and Lee used Department of Energy models in their work because those models are the most current. The goal of Atwood's and Curran's research is to develop validated models to predict reaction violence. That information can be used to determine how much time can be spent safely fighting a fire, which munitions are the most vulnerable, and how to load munitions more safely. [54]

F-16 JDAM Test Shows Joint Quick-Response Capability

Nothing accelerates the tempo of military support operations like a war. That was demonstrated in a marathon fix-test-field project that involved Edwards Air Force Base, the Land Range, and nearly a score of other organizations. The problem, which had shown up on the opening day of Operation Iraqi Freedom involving Block 30 F-16s operating in the Iraqi theater, affected JDAM. The software glitch was soon fixed, but the F-16 JDAM software had to be tested quickly on the China Lake ranges before it could be sent back to Iraq. Elapsed time from first call until the software was on its way to Iraq was 30 hours. "It was absolutely amazing how much we got accomplished in such a short period of time," said the 416th project pilot. "The same effort normally takes weeks." And apparently the Block 30 F-16s and their JDAMs are doing the job in Iraq. "The field hasn't come back with any complaints." [55]

Fire Scout Reaches New Heights

August 2003 saw Northrop Grumman's RQ-8A Fire Scout vertical take-off and landing unmanned aerial vehicle (VTUAV) making two crucial technology demonstrations—flying with a synthetic-aperture radar/moving target indicator (SAR/MTI) and completing initial at-sea testing aboard the amphibious transport dock, *USS Denver*. During these trials, Fire Scout flew over 10 hours of demonstration flights from NAS Patuxent River's Webster Field outfitted with a General Atomics SAR/MTI, which provided "very good imagery" at 1-foot and 4-inch resolutions, according to Northrop Grumman. As *JNI* went to press, Fire Scout was entering its second phase of at-sea testing, including flights out to the testing area from Point Mugu**,** where it will make low-speed approaches to *USS Denver* using the RQ-8A's Unmanned Common Automatic Recovery System (UCARS) and TCS. [62]

International Customers Receive Training on Sidewinder

Six Thailand Air Force and three Egyptian Air Force personnel completed training on the AIM-9M Missile System and support equipment. The Thai and Egyptian students completed their training on November 21, 2002. This was the first time two different countries participated in a combined training class. [54]

Navy and Industry Team Demonstrate Next-Generation Strike Warfare Architecture

A U.S. Navy and industry team completed the successful demonstration of the Enterprise Expeditionary Strike Warfare Architecture (eESWA), an advanced targeting and strike capability that will drive the requirements for network-centric strike systems of the future. The experimental demonstration showcases how a horizontally integrated, web-enabled capability can dramatically accelerate the sensor-to-shooter cycle from several hours to under 10 minutes. The initial eESWA demonstration, held in July at the Precision Engagement Center at China Lake, California, brought together for the first time an integrated, open architecture for intelligence, surveillance, and reconnaissance (ISR); time-critical targeting; and strike mission planning and execution. "Never before has the Navy been able to bring so many capabilities together in a horizontally integrated, open architecture," said Wendy Underwood, director of Navy command and control programs for Lockheed Martin Mission Systems. "This demonstration represents a tremendous step forward in determining the forward-looking strategy for programs like JSIPS-N and the Distributed Common Ground Station (DCGS)." [63]

Pegasus X-47A Takes First-Ever Flight Over Land Range

"We made history at China Lake today," said a flight test engineer. Northrop Grumman achieved a significant milestone in autonomously controlled flight February 23, 2003 with the successful first flight of its Pegasus experimental unmanned air vehicle (UAV). The flight took place at China Lake and lasted 12 minutes. Most significantly, the X-47A successfully landed near a predesignated touchdown point to simulate the tailhook arrestment point on a carrier flight deck. WD has been involved in UAV and unmanned combat aerial vehicle (UAV/UCAV) technology for several years. The war in Afghanistan has focused more attention on this emerging technology. [55]

SLAM-ER Launch Demonstrates New Capabilities

On May 6, 2003, aircraft and aircrew attached to Carrier Air Wing One (CVW-1) conducted a successful launch of the Standoff Land-Attack Missile Expanded Response (SLAM-ER). A direct hit was scored against the target, a simulated surface-to-air missile radar on the WD Sea Test Range, reinforcing SLAM-ER's reputation as the Navy's most accurate strike weapon. This launch was the first ever use of SLAM-ER in the Time Sensitive Strike role. Target coordinates and imagery were sent to the aircraft via the AWW-13 Data Link Pod using the Tactical Dissemination Module (TDM). The TDM node used was the Forward Dissemination Element 02, manned by personnel at China Lake. The Time Sensitive Strike conducted by CVW-1 demonstrated SLAM-ER's ability to strike targets from long range at a moment's notice. This launch was the culmination of a rigorous training program for Fleet aircrew provided by the Strike Fighter Weapons School Atlantic (SFWSL), SCWS, Boeing, NSAWC, and the SLAM-ER Tiger Team from Point Mugu. This launch was the first SLAM-ER missile firing to utilize airborne retargeting to strike an un-briefed target. [64]

Tomahawk "Firsts" for 2003

For the Tomahawk Flight Test Team, fiscal year 2003 was a year of firsts. During the year there was more Tomahawk testing than had been done in the past decade. Tests included the first two live fire flights of Tactical Tomahawk (TACTOM), first Tomahawk launch from an *Ohio*-class sub, TACTOM submarine launch, first use of CCS Mk II ECP IV combat control system for submarines, destroyer launch, use of the Penetration Variant, mission planned launch for both Block III (legacy Tomahawk) and Block IV (Tactical Tomahawk) using electronic tasking, use of the Strike Network to control TACTOM in flight and report health and status, embedded GPS TSPI for flight test, and first use of sub terminal TERCOM MAP Navigation utilizing new processes and databases for MAP Generation. According to Ted Mayle, VX-30 Tomahawk Project Officer at Point Mugu, "The Bloodhounds did an outstanding job. People who aren't 'in the know' probably don't have a true appreciation for how much work was necessary from so many people to consistently provide our chase and P-3 assets. It has been a blessing to have such a professional and dedicated aircrew who have saved the day many times." [65]

Electronic Warfare

EA-6B Integrated Product Team Supports Operation Iraqi Freedom

The EA-6B IPT at Point Mugu was recognized for a job well done in quickly fixing a software problem that was concerning warfighters flying EA-6B Prowlers in support of missions in Iraq. The EA-6B communications jamming weapons system, USQ-113, had been locking up for no known reason. The technical lead and software programmer for the USQ-113 correctly identified the root cause of the problem (a memory leak) and was able to rapidly write a software patch to fix the problem. His efforts from the time he read the first post-mission report to the release of a software patch, with NAVAIR's approval, was just under four months. As a result, the Fleet was able to load this patch prior to Operation Iraqi Freedom, where it was used in combat. [55]

ECR and T-SPIL Team Up

One morning at the Electronic Combat Range (ECR), 20 visitors joined the operations staff in the Test Control Center. As test time approached, all eyes were on the wall-mounted monitors that showed a view to the north, toward the Slate Range. On three monitors, a tiny dot appeared against the dark

background of the mountains. The dot quickly resolved into the image of an incoming F/A-18. Suddenly a string of infrared (IR) decoy flares shot from the F/A-18's on-board dispensers, creating bright white streaks on the monitors' displays. The top monitor was connected to a threat seeker mounted on a pedestal outside the Control Center. It showed a true "missile's eye view" of the F/A-18's approach. The second monitor displayed an IR image captured by a camera next to the threat seeker pedestal. The third monitor carried the output of an identical threat seeker located more than 20 miles away. That seeker was set up at the Threat Signal Processor in the Loop Facility (T-SPIL) and was fed the IR image from the camera at the ECR. The test at the ECR and T-SPIL brought the two facilities together, marking the advent of an enhanced capability for understanding threat systems in both the laboratory and the open-air test environments. [54]

Topgun's Best and Brightest Train at Electronic Combat Range

Some of naval aviation's best and brightest were flying and training above the Electronic Combat Range (ECR) at China Lake in late January. Each Topgun, naval fighter weapon school, class pits student pilots against the experienced threat radar operators and their many threat radars at this NAVAIR range. Topgun students train against realistic threat radar and surface-to-air missile (SAM) systems. The pilots test their skill against instructor pilot and ground-based radars. Students experience air-to-air combat against instructor pilots. These Topgun candidates gain familiarity and expertise flying in the "missile zone," watching their threat-warning screens for radar tracking and fire control lock-on by a threat. Four and sometimes as many as six different radar systems are used against the student pilots during the missile zone engagement.[54]

Survivability/Vulnerability/Lethality

Live Test Assesses C-130's Vulnerability to MANPADS

The vulnerability of large, fixed-wing aircraft to small, inexpensive, shoulder-launched antiaircraft weapons is being investigated. China Lake's Survivability Division conducted a vulnerability test of a C-130 aircraft by firing a live Stinger missile at it. Fired from a 12-pound launcher, the missile tracks an aircraft's IR signature and makes the kill with an impact-fuzed high-explosive warhead. The goal of this test was to obtain data from an actual missile/aircraft interaction—data that will be used to refine and validate vulnerability analysis computer models. Ultimately, the goal is to determine how survivable the C-130 is and to investigate ways to further reduce the vulnerability of the C-130 and other aircraft to MANPADS. This test marks another milestone in NAVAIR's live-fire test capability. Data from these tests will lead to aircraft that are less vulnerable, more survivable, and more likely to bring their aircrews safely home at mission's end. [54]

MANPADS Testing Provides Modeling Data for the Joint Strike Fighter

Man portable air defense systems (MANPADS) underscore the asymmetric nature of modern warfare—one person toting a $25,000, IR-guided missile can, in theory, destroy a military aircraft. Two primary approaches to MANPADS defense are susceptibility reduction and vulnerability reduction. On the susceptibility front, many tactics and devices are designed to evade, divert, or destroy IR-homing missiles. The Tactical Aircraft Directable Infrared Countermeasures (TADIRCM) system, for example, detects an approaching threat and disables it through the use of directed laser energy. Vulnerability picks up where susceptibility leaves off. Vulnerability reduction begins with a question: if the countermeasures don't work and the missile strikes the aircraft, what are the consequences? To address that question, Joint Strike Fighter (JSF) Live Fire Test #08A MANPADS Characterization (LFT #08A) was conducted at NAVAIR China Lake's Weapons Survivability Laboratory (WSL). Previous MANPADS testing conducted at the WSL included live Stinger firings against two F-14s, an F-16, a structural test article for a composite helicopter, and a C-130. The JSF Live Fire Test Master Plan calls for an evaluation of the effect of a MANPADS missile impact on the JSF aircraft. But while dynamic impacts against real aircraft components are instructive as to the nature and degree of actual damage, the results are complex and not well suited to enhance modeling capabilities used for system design. [54]

Survivability Division

NAVAIR Weapons and Aircraft divisions, the FAA, the Air Force and NASA Glenn have teamed up. Turbine engine disk failures, although rare, are a leading propulsion-related safety hazard in commercial aviation. Fan disk failures, in particular, pose a threat due to the size and number of fragments liberated during an uncontained engine failure. At the Weapons Survivability Laboratory at China Lake, numerous crack-detection technologies were demonstrated. Survivability professionals say that the successful demonstration will create a cornerstone for further government collaboration in aircraft safety research to pursue "On-Aircraft Engine Disk Crack Detection" technology development. Such technology would enable detection of impending engine failures during flight or ground operations, enabling the aircrew to take action to prevent a catastrophic engine failure that could result in loss of an aircraft and passengers. [54]

Virtual Flight Testing Returns to HIVAS

Missile development engineers are continually seeking higher fidelity ways to test weapon performance. In support of the quest for better test methods, NAVAIR turned to the Weapons Survivability Laboratory (WSL). Nearly two years after virtual flight testing (VFT) made its debut at China Lake, the VFT team again "flew" a BOA missile at the WSL. Suspended on six wire rods within a 16- by 16-foot framework in front of the High-Velocity Airflow System (HIVAS) outlet, the missile made seven flights, at airspeeds up to 450 miles per hour. Live flight-testing is the best. However, it is expensive (particularly

for air-launched weapons), is short on controlled repeatability, and usually ends with the loss of a valuable test asset. Computer simulations are extremely useful. But even the most sophisticated computer simulations cannot capture the millions of variables that influence a weapon's in-flight performance. Wind-tunnel testing comes closer to reality, but it is usually done with models and doesn't include the missile control systems. At the Air Force's Arnold Engineering Development Center (AEDC), full-size missiles can now be tested in the 16T (Transonic) Tunnel at airspeeds up to Mach 1.6. VFT's goal is to develop a controlled flight test capability for AEDC's 16T Tunnel. Developers and designers will be able to observe the dynamic interaction among a missile's airframe, control mechanisms and software, and the flight environment, all under controlled conditions. [54]

Modeling and Simulation

2003 Modeling and Simulation Award Winners Announced

The Department of Defense announced the recipients of the 2002 Defense Modeling and Simulation (M&S) Awards. In the analysis category, the winner was the Threat Signal Processor-in-the-Loop (T-SPIL) Team, at NAVAIR China Lake. Each year, the DOD M&S Awards Program recognizes units, organizational elements, and individuals (civilian employees and active duty service members) of the DOD components for excellence, innovation, and achievement in advancement of "state of the art" M&S. Recognition is also given to contribution towards interoperability and reuse in support of DOD M&S objectives. The awards program is sponsored by the Under Secretary of Defense for Acquisition, Technology, and Logistics. Dr. Ronald Sega, director of Defense Research and Engineering and chair of the DOD Executive Council presented awards for Modeling and Simulation. [66]

Research, Science, and Technology

Nonlinear Optical Polymers (NLOPs) for Precision Navigation/Data Transmission

Chemists at WD have developed several nonlinear optical polymers that offer lower cost and higher performance in fiber-optics, avionics, and photonics applications. For example, these polymers will become part of a revolutionary new guidance capability that will allow troops to stand off at great distances, out of harm's way, and take out enemy targets with pinpoint accuracy. The NLOP research field is growing rapidly, and new developments have the potential for providing exciting new devices and systems for the telecommunication and data communication industries at 10 times greater bandwidth. At WD, new NLOPs are under development for use in high-speed optical signal processing devices, such as electro-optic modulators, optical switches, and frequency doublers. [59]

Fiber-Optic Gyroscope (FOG)

An exciting new fiber-optic gyroscope is being developed at China Lake. For military applications the FOG is being developed for use in inertial measurement units (IMUs) and was originally intended for use in missile guidance packages. However, the FOG could further broaden the already expanding market in accurate navigational systems for private and commercial boats, planes, and other vehicles. It may also have applications for satellite-borne systems. The FOG is an angular-position indicator that offers better performance—and potentially higher reliability and significantly lower cost—than existing mechanical gyros. [41]

Plastic Metal. Visibly Transparent, Electrically Conducting Polymers

Chemists at WD have synthesized an electrically conducting polymer that is transparent in the visible region of the spectrum. Applications range from RF-reflecting sensor windows to electrically generated camouflage and dial-in window tinting. This "green" technology from a power consumption perspective could revolutionize the window industry. Another commercial application would render carpet fibers electrostatic-free. Other work is focusing on application to metals as a corrosion inhibitor. In addition, the polymers are being investigated for use in super capacitors that could be used in hybrid or all-electric cars. [59]

Waste-Incineration Technology

Efficient, high-temperature, waste-incineration technology has been developed and demonstrated at China Lake. This technology allows smaller units to incinerate larger quantities of waste, using less fuel and with fewer by-products, than current commercial incineration processes. In the course of investigating air-breathing (ramjet) combustion technology for aircraft and missile applications, researchers at China Lake have developed continuous, computerized combustion-control technology that maximizes the heat and optimizes the location of combustion vortices within the combustor unit. This technology can be incorporated in small, portable combustion units for on-site waste incineration, eliminating the storage and transfer costs associated with removing waste to central incinerating locations. [41]

Direct Fleet Support

Joint Fleet Exercises

Point Mugu received the following Bravo Zulu from Commander, Carrier Group One for support to Composite Unit Training Exercise (COMPUTEX), which preceded Joint Task Force Exercise 3-2. The Surface Targets support personnel provided opposing forces ("bad guy") services to the Fleet. WD will also participate in future COMPUTEX with small boats as Visit, Board, Search, and Seize (VBSS), Maritime Intercept Operation (MIO), and Swarm Exercise (SWARMEX) targets. [55]

"Please extend my sincere appreciation to your outstanding cadre of surface units who formed the [Surface Warfare] SUW opposition forces and provided target vessels in support of the Nimitz Battle Group COMPUTEX/JTFEX…The Nimitz Battle Group was exposed to realistic contacts of interest, which significantly enhanced their overall surface warfare training. Your efforts were essential to the integrated multi-mission training…Again, thank you for a job extremely well done."

—RADM Hines
Commander, Carrier Group One

Fleet Weapons Support Teams

WD's Fleet Weapons Support Team (FWST) played a significant role in the success of deployed forces during Operation Iraqi Freedom. Professionals ensured that weapons were capable of performing their mission. FWST representatives also provided essential real-time training to ordnance personnel and aircrews, as well as serving as the corporate connection back to weapons program managers who could identify and correct logistics deficiencies on the battlefield. [55]

JDAM. WD's FWST assisted Marine Air Logistics Squadron Eleven (MALS-11) with buildup of Mk 83 bombs to JDAM units and assisted Carrier Air Wing Five (CVW-5) Ordnance regarding fuze function delay options for GBU-32/35. [55]

JDAM Fleet Training/Optimizing Performance. NAVAIR Fleet Weapons Support Team (FWST) personnel were deployed on-board *USS Kitty Hawk* to provide training and support for CVW-5 during their initial JDAM captive flight training. [55]

Sidewinder. The FWST provided forward-deployed support on 32 AIM-9M Sidewinder missiles and technical assistance to Marine Aviation Logistics Squadron (MALS)-31 Ordnance personnel on implementing Air Weapons Bulletin (AWB)-405 on 13 Sidewinder missiles that they had received. The FWST assisted *USS Harry S. Truman* (CVN-75) in troubleshooting and fixing an F/A-18 AIM-9 squadron wing tip station problem. [55]

Technical Assistance. The FWST provided "in theater" weapons/weapons systems assistance, ashore and afloat, in support of the First Marine Expeditionary Force (I MEF) and the Third Marine Aircraft Wing (3rd MAW). [55]

Documentation. The FWST provided updated versions of all gun, launcher, and rocket manuals to *USS Saipan's* Aviation Intermediate Maintenance Depot. They provided Support Equipment Change documentation for their common rack and launcher test sets. [55]

Laser Guided Bomb (LGB). The FWST assisted fixed-wing munitions personnel and aircraft operators in determining the cause of failure of several LGB weapons. [55]

LAU-116A/A Missile Launcher. The FWST assisted MALS-31 with troubleshooting and repairing an electrical problem they encountered while conducting electrical checks on the Common Rack and Launcher Test Set (CRALTS). [55]

JSOW. The FWST assisted forward deployed forces with Airborne Weapons Bulletins (AWBs) concerning software configuration of certain weapons. [55]

NAVAIR on *Nimitz*. China Lake engineers traveled to *USS Nimitz* during a Composite Training Unit Exercise on the Sea Range, part of final preparation of the *Nimitz* for the Persian Gulf. Engineers trained operators to develop target packages on the Precision Targeting Workstation and pass them to the Digital Camera Receiving System. From there, the packages can be sent to airborne F/A-18s equipped with the Fast Tactical Imagery (FTI) system. Engineers also investigated problems with the FTI link between the ship and the aircraft. NAVAIR engineers fixed the problem, allowing voice and imagery transmissions and generated a user's manual for the staff. [55]

***USS Nimitz* Readied for War**

USS Nimitz (CVN 68) is one of the largest fighting ships ever built. Displacing more than 95,000 tons, the nuclear powered aircraft carrier reaches 18 stories from keel to mast top and measures more than one-fifth of a mile from bow to stern. Engineers from NAVAIR's Weapons Engagement Office (WEO) at China Lake traveled to *Nimitz* in late January during a Composite Training Unit Exercise (COMPUTEX) on the Sea Range. This COMPUTEX was part of *Nimitz'* final preparation for deployment. It was also the first time since the overhaul that the entire *Nimitz* Carrier Battle Group had come together in a coordinated effort to carry out mission-specific tasks. NAVAIR was called in to help the ship's crew master the process for developing targeting packages and transmitting them to the F/A-18s of Carrier Air Wing 11 (CVW-11), *Nimitz'* primary offensive weapon. The NAVAIR engineers met with the Sailors who operate the imagery and targeting systems. Over the course of the next two days the NAVAIR teammates worked side-by-side with Navy operators and technicians, showing them how to develop target packages on the Precision Targeting Workstation, transfer them to the current operations watch officer for review, and then pass them to the Digital Camera Receiving System (DCRS). From there the packages can be sent to airborne F/A-18s equipped with the Fast Tactical Imagery (FTI) system. [54]

NAVAIR's Warfighter Response Center (WRC) Links Warfighters to Engineers

During Operation Iraqi Freedom WD's WRC was manned 24/7 resolving difficult issues for warfighters from the Navy, Marine Corps, Army and Air Force. For example, an Air Force pilot experienced some problems dropping a particular weapon in theater. Within hours, WD engineers were testing the proposed solution on the Land Range. By the end of the same day, the fix was on its way to Iraq. WRC has four SIPRNET terminals with secure e-mail and VTC services and full support for recall, logistic, and deployment of reservists. The WRC also teamed up with NAVSEA for expanded

services. As part of NAVAIR's response network, the WRC helped with questions or data calls on Operation Enduring Freedom and Noble Eagle. The WRC is linked to the Force Protection Condition command and control and the Emergency Operation Center. Fleet help desks and call centers are at NAVAIR's national level of attention and are directly linked to the Navy's Integrated Call Center located in Norfolk, Virginia. The WRC has already resolved many difficult issues for warfighters from the Navy, Marine Corps, Army and the Air Force. Just before the conflict in Iraq began, pilots flying over Baghdad observed oil-filled ditches all around the city and were concerned that if the oil was ignited, the smoke would affect the accuracy of the precision laser-guided munitions they were going to use. Before the day was out, WD engineers had consulted their subject matter experts, developed tactics for weapons employment, and had the solution to pilots in theater. Another call came from an Air Force pilot who experienced problems dropping a particular weapon in theater. WD engineers were contacted via our neighbor, Edwards Air Force Base, requesting a software update for that weapon. Again, WD was able to identify the problem and come up with a solution that was tested on the Land Range to make sure it worked. In short, in a little more than a 24-hour period, WD identified and fixed the problem, tested it, and had the new fix in theater for the pilots to use. [55]

NAVAIR's WRC Provides Direct OIF Support

The WRC provided planning, coordination, deployment, and 24/7 support for the combat deployment of two NAVAIR prototype systems: the Tactical Dissemination Module/ Rapid Precision Targeting System (TDM/RPTS), and the Digital Precision Strike Suite (DPSS).

The forward-deployed WD team, civilian and contractors, transported and set-up the TDM/RPTS system at Prince Sultan AFB Saudi Arabia and Ali Al Salem Kuwait. The WD team quickly integrated the system into the Combined Air Operations Center and it became operational in just one month. WRC coordinated TDM training, provided pre-deployment protective uniforms and gear, and assisted with medical screening/vaccination/prescriptions to meet CENTCOM-specific requirements. During OIF to date, TDM/RPTS successfully executed more than 1,000 combat missions to multiple aircraft, including the B-52, B1B, F-15E, F-18s, F-14 and S-3Bs. The WRC also conducted more than 300 Situational Awareness (SA) missions, providing ground forces with SA imagery products to identify and locate improvised explosive devices.

WRC was also instrumental in forward-deploying the prototype DPSS system in direct response to warfighter needs for the portable generation of targeting quality coordinates. The United States Joint Forces Command partnered with the NAVAIR Weapons Engagement Office to refine this existing capability and formalize DPSS training for all Joint Terminal Attack Controllers (JTACs). Training and fielding to Special Operation Forces is in progress. DPSS is currently fielded in numerous warfighter units, including SEAL teams on both coasts, the 720th Special Tactics Group (AFSOC), West Coast Marine Units (I MEF), and selected U.S. Army Special Forces.[168]

Homeland Defense

FBI Uses China Lake for Crime Scene School Classroom

More than 1,000 pounds of deadly explosives packed inside an empty bus detonated at the Supersonic Naval Ordnance Research Track (SNORT)—replicating the Bali terrorist attack—creating a simulated crime scene for the FBI Large Vehicle Bomb Post Blast Crime Scene School. In early 2003, the FBI school came to NAVAIR China Lake for the eleventh time. According to the FBI Special Agent running the training, "we can do larger detonations here. The relatively pristine range allows students to identify part of the vehicle and the bomb after the explosion." One of the students, a member the NYPD Bomb Squad said, "No other class offers such experience and expertise. We sure can't do something like this (blow up a bus with 1,000 pounds of explosives) in New York City." [54]

PRISM Helps the FBI Keep Commercial and Military Aircraft Safe From MANPADS

Shoulder-launched, infrared-guided, man portable air defense systems (MANPADS) are a significant threat to the safety of commercial aircraft. "Anywhere in the world where military or commercial aircraft take off or land, the PRISM (Portable Resource for the Investigation of Suspected MANPADS) system can identify locations where MANPADS could be launched toward aircraft," according to a NAVAIR survivability engineer. Having previously worked with the FBI and the National Transportation Safety Board (NTSB), China Lake proposed development of a computer-based information system. The FBI has funded an update to the prototype to include threat launch envelopes for determining airport security zones for 80 airports. These zones are plotted by a flight-path threat-analysis simulation provided by the Missiles and Space Intelligence Center (part of the Defense Intelligence Agency) in Huntsville, Alabama. [54]

Special Weapons and Projects

Tunnel-Warfare (Future Potential)

China Lake is on the same latitude as Kabul. It has a very similar landscape, including the bushes, trees, and rocks. Geologists have identified more than 300 abandoned mines. Some of them date back to California's gold-rush era in the 1850s. Three of the tunnel locations are fully instrumented with weather stations and environmental sensing equipment inside and outside. The weapons and tactics being developed at China Lake may be useful against the war on terrorism. [67]

Closing Circle Will Push War Bunkers Protect Iraqi Leaders. Over the past 20 years, Iraqi President Saddam Hussein is believed to have constructed an elaborate series of

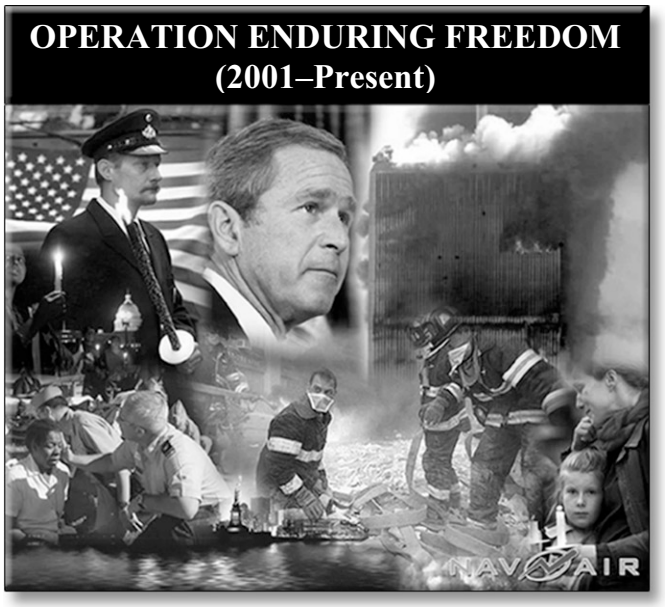
underground tunnels and bunkers around Baghdad where he, his leadership, and the elite troops that guard them are able to move about virtually undetected and nearly impervious to U.S. munitions. Among the more extensive tunnel complexes are those described by Hussein Shahristani, once Iraq's top nuclear scientist, who was tortured and imprisoned in Iraq. Shahristani, who escaped Iraq during the first Gulf War, said that subway plans developed by several foreign firms were actually used by the Iraqi military to hide and transport the country's chemical and biological weapons. Shahristani told CBS's "60 Minutes" in February that he believed Iraq had "more than 100 kilometers of very complex network, multi-layer tunnels." Finding tunnels and bunkers has become a priority for U.S. military and intelligence in the past several years. A batch of technological innovations is allowing the U.S. government to better understand what's below the surface. Among them are seismic devices akin to big hammers that pound the ground and bounce back a signature like radar. Experts also use gravimeters, which measure the variations in the gravitational field between two or more points to help pinpoint underground installations. Special high-flying spy cameras that measure thermal energy and chemical releases are used to find clues that may indicate the presence of underground activity. The U.S. military is also developing new targeting techniques, fighting tactics, and intelligence gathering about underground facilities.

In 2002, during the war in Afghanistan, the Navy began looking at locations where the U.S. could better train and prepare for international conflict. At China Lake, the 1.1 million-acre test and training range has 300 miles of abandoned mines that resemble the bunkers, vertical shafts, and multilevel tunnel complexes of Afghanistan and Iraq, she said. [68]

VX-30 Turns a Tomcat Into a Bombcat

With only three weeks notice, VX-30 was asked to make a 1958 Vietnam-era DC-130A capable of deploying the Air Force version of the BQM-34 subscale target in support of Operation Iraqi Freedom. Engineers, maintenance and target shop personnel, and project officers worked around the clock to complete the testing and evaluation necessary to meet the Joint Chiefs of Staff deadline. Thirty-four crew members made the four-day trip to Kuwait. During the 18-day deployment, the DC-130A flew in two successful electronic warfare night-combat missions. The military/civilian team had met the challenge by turning a Tomcat to a Bombcat. Software integration was performed on three aircraft carriers in two oceans in three weeks. [55]

Old 'Flying Taco Stand' Not Too Worn to Do the Trick. "It's been an adventure, no question about it," said Cmdr. Steve Gasporovich, the executive officer of VX-30, a Navy air test and evaluation squadron based at Point Mugu. The orders given Gasporovich and Maj. Robert W. Baxter of the Air Force Reserve the first week of March were simple: Fly the C-130 more than 9,000 miles from California to this desert base, and prepare the airplane to launch five jet-powered drone aircraft toward Baghdad. The aging C-130 was dubbed the Flying Taco Stand because of its unique color scheme. The objective of the mission was to trick Iraqi air defense gunners into firing at "ghost" planes before the waves of coalition aircraft struck. The two veteran aviators left California on March 11 and arrived at the desert base on March 18, the day before the war began with the "decapitation" bomb-and-missile strike aimed at Saddam Hussein's bunker in Baghdad. Changing pilots in-flight and stopping only to rest the 11-man crew, the C-130 was in the air for 32 hours for four days. After they arrived, the crew worked quickly to mount the cargo, five jet-powered drones, to pylons beneath the wings. Each drone carries six canisters loaded with 96 shotgun-shell-sized charges of chaff, which are fired remotely. The crew launched three Firebees programmed to fly to Baghdad, on to Tikrit—Saddam's hometown and his power base—then back to Baghdad, making multiple passes dispensing chaff over the Iraqi capital. [69]



Weapons and Weapon Systems

Cruise Missile Real-Time Retargeting (CMRTR)
CMRTR is improving strike weapon systems that seek fixed and time-critical mobile targets. The seeker uses a high-resolution LADAR sensor to create a three-dimensional image of ground objects. These data are then processed in real time by automatic target recognition (ATR) algorithms to identify specific targets. The goal is to identify targets 90% of the time with less that a 0.01% false alarm rate. This concept was initiated in FY95. Three-dimensional data were observed to offer the best opportunity for ATR to work. This project evolved into a joint Air Force/Army effort to further develop LADAR. A tactically sized system with both missile and surveillance applications is planned for FY05. This system represents the first medium-range high-resolution imaging seeker suitable for use with ATR algorithms for detection and identification of ground targets. [70]

Joint Direct Attack Munition (JDAM)
Achieved Initial Operational Capability (IOC) For JDAM In April 2001. The baseline JDAM achieved IOC in April 2001. This milestone was achieved in time to take action in the war on terror in October 2001, and JDAM soon established itself as the weapon of choice in OEF. [71]

GBU-32 (1,000-Pound) JDAM Enters Fleet with System Configuration Set (SCS) 15+. WD released to the Fleet the F/A-18 SCS 15C+ software package that enabled the F/A-18 community to be first in line for the GBU-32 (Mk 83, 1000-pound variant). Early operational capability was declared after a VX-9 quick-reaction assessment. GBU-32s were rushed in theater for OEF. Additionally, 11 live fires to evaluate a new inertial measurement unit for JDAM have been successfully completed. GBU-38 (Mk 82, 500-pound variant) separation testing has begun at Patuxent River in support of weapon system integration. GBU-38 will require SCS 19C and the BRU-55 "smart rack." [71]

500-Pound Versions Completed Critical Design Review (CDR) in December 2001. WD began development test of the Mk 82/BLU-111 GBU-38/B JDAM in 2002. These 500-pound versions of JDAM require repackaging to accommodate the smaller size of the Mk 82/BLU-111 warhead. The flight tested the introduction of the BRU-55 Smart Canted Vertical Ejection Rack bomb rack assembly to allow the F/A-18 to carry eight independently targeted JDAMs. This variant is scheduled for IOC in 2004. [71]

Precision Guided Weapon (PGW) Planned. WD began preparation for the PGW to improve delivery accuracy as part of the preplanned product improvement of the JDAM weapon system in 2002. Documentation necessary for contract award and Milestone B was identified and early engineering studies undertaken prior to contract award. [71]

> "In Desert Storm, we scheduled into the tens of aircraft per target. In Operation Enduring Freedom, Navy tactical air on average struck more than two targets per aircraft that delivered ordnance."
>
> —VADM John B. Nathman, Commander, Naval Air Force, U.S. Pacific Fleet, *U.S. Naval Institute Proceeding*, March 2001.

> "One third of the ordnance dropped in the Kosovo campaign was precision-guided. The figure is 60% for the Afghan air campaign."
>
> —Robert Wall, "Targeting, Weapon Supply Encumber Air Campaign," *Aviation Week*, October 22, 2001, P. 26.

> "JDAM has been the weapon of choice in Afghanistan, where more than 4,200 have been dropped, about one-third of all the munitions used in the war."
>
> —Eric Schmitt and James Dao, "Use of Pinpoint Air Power Comes of Age in New War," *The New York Times*, December 24, 2001, P. 1.

Joint Standoff Weapon (JSOW)
Used with Devastating Effect. A popular armament selected for strike missions during Operation Southern Watch was the JSOW, a long-range unpowered glide weapon. Fleet aircrews prefer JSOW because its large standoff distance permits it to be launched from well outside the range of most threat air defenses. Since the weapon's first tactical employment in January 1999, U.S. forces have employed more than 100 weapons as JSOW has proved its combat effectiveness in Operation Southern Watch, Operation Allied Force, and OEF. These Fleet activities were supported by WD personnel with onsite visits to Fleet carriers in the Persian Gulf, the Mediterranean, and the Far East to provide on site training and weapons introduction support. [54]

Improved Performance with Quick Tactical Refinements. Field reports from in theater use of JSOW indicated an accuracy problem in one missile. NAVAIR Command and senior staff were immediately briefed on the situation. That same day, an ad hoc team of experts from across the Division was assembled. Every possibility had to be weighed and every factor considered. Was the problem in the hardware, software, mission planning, or weapon loadup? Or could the problem be related to weather, jamming, or the tactics employed? As the team worked day and night, the simulations being run at WD and Raytheon began to point to a probable cause of the problem. A tactical refinement worked perfectly in the hundreds of simulations, but for absolute confidence it needed to be validated through actual flight testing. That validation was achieved on the Land Range at China Lake. Three JSOWs, one inert and two live, were launched. The launch scenarios were carefully constructed to demonstrate that the Fleet recommendations would result in the desired performance. That goal was met. The successful completion of this effort was passed to NSAWC, which then distributed this information to Fleet users. [54]

JSOW Unitary Scores in Third Free-Flight Test. Flies 12 miles and hits target with surgical precision. Second floor, middle window, please. The targeting seemed almost that simple as an AGM-154C JSOW demonstrated an accuracy seldom seen in an autonomous standoff weapon: flying 12 nautical miles before striking a Land Range target with near-surgical precision. In its third successful free-flight demonstration, the Navy/Raytheon-developed JSOW Unitary variant (the JSOW-C) attacked a specially constructed vertical target at Cole Flat. The event marked the conclusion of the contractor's seeker-development and targeting-algorithm test series. "JSOW Unitary continues to meet or exceed performance expectations," said CAPT Robert O. Wirt Jr., JSOW Program Manager. "This is yet another example of the platinum standard exercised across NAVAIR. The capability demonstrated with this test will further enable absolute combat power for the warfighter."

CDR Andrew "Harley" Hartigan, a member of VX-31 (formerly Naval Weapons Test Squadron (NWTS) China Lake), stated, "It's absolutely incredible to be able to put a weapon through a window from that standoff range. That's an unsupported weapon—no lasing, no man-in-the-loop, just the JSOW on its own. We've reached a whole new level in strike warfare." [54]

Launchers

Transportable Ballistic Target Launcher Shows Capabilities at San Nicolas Island on the Sea Range. A target simulating a threat ballistic was launched from San Nicolas Island and flew 278 kilometers downrange and reached an apogee of a little over 88 kilometers above the Sea Range. The event was the initial test of the Transportable Ballistic Target Launcher, the product of a WD initiative to develop low-cost targets and a launch capability for Theater Ballistic Missile (TBM) defense. Since the Gulf War of 1991, there has been increasing awareness of the threat posed by tactical ballistic missiles. Iraqi forces were successful in using the Scud to harass and terrorize opposing forces. Many weapons have fairly short tactical ranges and could be used to attack ports, cities, and choke points in the ocean. Services are developing weapons to counter hostile ballistic missiles in the battlefield. To adequately test these weapons they need ballistic simulations of the threat. Solutions include overhead sensor developments, phased-array radar improvements, sophisticated guidance and warhead upgrades, and new developments such as airborne lasers. The transportable rocket launcher, developed by the NAVAIR White Sands team, consists of a launch rail and raising mechanism mounted on a standard 40-foot trailer. Launcher deployment can be done in a quick and efficient "campaign" style, where everything comes in on one or two loads. [54]

Laser-Guided Bombs (LGBs)

BLU-116 Enters Production. The BLU-116A/B is a hard-target deep penetrator that will be used in the GBU-24G/B weapon system. The bomb was designed by the China Lake Warhead Development Branch; prototypes were manufactured by the Michelson Laboratory machine shop; and the bombs were explosive-loaded and assembled by the China Lake Propellant and Processing Branch. "Now until the end of 2004, we will be manufacturing, explosive-loading and assembling all components into the BLU-116A/B assembly and then delivering prototypes to the Fleet," said Scott Greenmun, project lead in the China Lake Tactical Weapons Office. Procurements and machining operations are completed at China Lake. The units are sent to contractors for plating/coating and painting. The Propellant and Processing Branches at China Lake and the Naval Surface Warfare Center (NSWC), Indian Head Division, Yorktown Detachment perform the explosive loading of the penetrator cases. Captive flight tests and launches of the GBU-24G/B are scheduled to take place in 2003. [54]

Laser Guided Bomb Mission Planning Tool. A WD employee on detail to the Naval Strike and Air Warfare Center (NSAWC) who became involved in an effort to improve mission planning for laser guided bombs (LGBs) developed a graphical user's interface (GUI) for the Naval Stores Planning and Weaponeering component of the Joint Munitions Planning System (JMPS). Fleet support at NSAWC and Weapons Schools turned the GUI development into a stand-alone program. WD enhancements evolved from interactions with warfighters and expertise in weapons systems. WD integrated Joint Munitions Effectiveness Manual (JMEM) hard-target penetration tools into a Paveway Munitions Planning Tool (PMPT), providing a "one stop" tool for LGB mission planning. The PMPT is a Paveway II and Paveway III LGB mission planning tool that provide users with a Launch Acceptability Region (LAR) from which to release weapons, to calculate single trajectories for time-of-flight and lasing time analysis, and to compute penetration into hardened targets. It runs on Windows operating systems. Version 1.0

was released to the Fleet in June 2001. Both the Air Force and the Navy used the PMPT successfully in Operations Enduring Freedom and Iraqi Freedom for LGB mission planning. [73]

Low-Cost Guided Imaging Rocket (LOGIR)

LOGIR is a low cost accuracy enhancement kit for existing rockets. LOGIR will do for rockets what JDAM did for iron bombs. The LOGIR project began in 2000 and is still underway. Its primary objective is to significantly improve the warfighter's ability to address moving and fixed targets with an emphasis on moving targets. In order to achieve this objective, LOGIR must reduce warfighter exposure and provide less than one-meter precision all at very low cost. Existing weapons require helicopters to locate the target, point the weapon by pointing the helicopter, designate the target, and fire. In most cases, the helicopter must stay locked onto the target until weapon impact. This requires the helicopter to stay in a fixed position, sometimes for several minutes, in order to fire a single weapon, therefore making helicopters extremely vulnerable. LOGIR is launch and leave. LOGIR allows the warfighter to designate the target using the existing targeting FLIR. Once designated, the pilot can fire the rocket and leave the area. LOGIR will use the FLIR targeting data to fly to the target, and acquire and track the target to weapon impact. LOGIR is inexpensive because it uses low cost commercially available components like the uncooled focal plane array, low cost MEMS based IMU technology, and injection molded composite construction all in a fully strap-down package with no moving parts. [125]

Phalanx

Phalanx is Installed on Every U.S. Combatant Ship, as Well as on Combatant Ships of 20 Allied Nations. Just as the phalanx formation of ancient times appeared to the enemy as an encroaching wall of spear points, the Phalanx of today creates a modern-day wall of points that stops the enemy (in this case, the incoming threat) in its tracks. The firing is so rapid that observers hear a steady roar rather than individual shots. The Phalanx, a rapid-fire, computer-controlled radar and gun system, is used to defeat both anti-ship missiles and other close-in surface and air threats. As a self-contained package, once armed it automatically carries out search, detection, target threat evaluation, tracking, firing, and kill assessment. The manufacturer, Raytheon, states that the Phalanx is installed on every U.S. combatant ship, as well as on combatant ships of 20 allied nations. [54]

Testing at China Lake Proven to be Very Cost Effective. The senior systems engineer at Raytheon Tucson and his test team were at China Lake for operational testing on the third version of software for the Phalanx 1A gun system. The 150-mm howitzer shoots projectiles at the Phalanx gun system to simulate incoming anti-ship threats. Phalanx must acquire, track, and shoot down these threats. The software incorporates more than 180 changes aimed at enhancing system performance. "We get great support from the team here on the land ranges at China Lake," according to a Raytheon senior engineer. "If we did these tests on ships, it would be a much higher cost. We'd have to take the ships out of port each time, costing thousands and thousands of dollars. Utilizing the radars and missiles needed, getting the F/A-18s into the air to launch missiles at us, it would be up around a million dollars. Here, we can essentially conduct the same type of test using the 155-mm howitzer targets and it's very cost-effective. We can just shoot and shoot. At this point in our testing, we must have tactical engagements. And we can do that at China Lake with proven support personnel." [54]

Pulse Detonation Engine (PDE)

The engine bolted to the test stand looks like an unlikely candidate to lead an aerospace revolution. Its size is unimpressive: about four feet long and dwarfed by the machinery that feeds it air and fuel at China Lake. This aircraft engine is the most advanced expression yet of a revolutionary concept called pulse detonation. Showing that the concept behind this engine can open up an entirely new world of jet propulsion has taken years. In the past 10 years, the promise of a propulsion system far simpler than today's turbofans and capable of operating across a much wider velocity range, powering aircraft from takeoff to Mach 4 with ease, has touched off an explosion of interest at university, military and NASA research centers, and in labs as far away as Japan, France and Russia. The concept behind the PDE is deceptively simple. In short, there are two kinds of combustion: the old, familiar, slow kind of burning, called deflagration, and another, much more energetic process called detonation, which is a different animal entirely. Imagine a tube, closed at one end and filled with a mixture of fuel and air. A spark ignites the fuel at the closed end, and a combustion reaction propagates down the tube. In deflagration—even in "fast flame" situations ordinarily called explosions—that reaction moves at tens of meters per second at most. But in detonation, a supersonic shock wave slams down the tube at thousands of meters per second, close to Mach 5, compressing and igniting fuel and air almost instantaneously in a narrow, high-pressure, heat-release zone. The military will help fund the project and has given the team a simple, small-scale test platform for the technology. Later, a "supercharged" version of the pure PDE may be followed by a conventional turbofan with pulse-detonation tubes mounted in the bypass duct around its compressor—a so-called duct burner. [74]

Standard Missile 3 (SM-3)

Theater Ballistic Missile Defense (TBMD) Office Established. First Sea-Based Intercept. WD established the TBMD Project Office in 1992 to defeat short-, medium-, and long-range ballistic missiles carrying warheads capable of mass destruction (conventional, nuclear, chemical, biological, etc.). WD is developing and testing the Standard Missile 3 (SM-3), which fires from an Aegis cruiser and intercepts a ballistic missile in the exoatmosphere. WD is also developing sea-based kinetic-energy boost-phase-intercept missile technology. Kinetic technology refers to intercepting a ballistic missile by ramming it with another missile while it is

still in its boost phase of flight (before it leaves the atmosphere). There is no explosive warhead on the intercepting missile. The target missile is destroyed by the force of the collision (called hit to kill), comparable to a bullet hitting a bullet. WD supports work being done on the kinetic warhead, the third-stage rocket motor, risk reduction, and axial propulsion. (Axial propulsion is a rocket motor that propels a missile forward from the back end, as opposed to a rocket thruster that exhausts its gases out the side, propelling the missile to the side.) The Team's participation has led to the first SM-3 firing, Control Test Vehicle 1A, which was successfully launched from *USS Shiloh* in 1999. In 2001, Flight Test Round-1A was successfully launched. During 2002, WD participated in three successful flight tests performed at the Pacific Missile Range Facility in Kauai, Hawaii, resulting in the first ever sea-based ballistic missile intercepts. These flight tests were preceded by extensive design reviews, modeling analyses, and component-level tests. WD contributions include the IR Seeker, optical performance, all-reflective optics, sensitivity, permeation analysis, discrimination, cryogenics, two-color focal plane arrays, guidance and control, and propulsion. The first of these missiles is scheduled to be deployed, by direction of President Bush, near the end of 2004. [75]

Sidewinder

All U.S. and Allied fighter aircraft operating in OEF carry the Sidewinder air-to-air missile. Sidewinder was born at WD, and the Division continues to be the primary government technical support for every U.S. variant. [76]

Repaired Sidewinder Guidance and Control Sections. NAVAIR WD completed repair of the ten AIM-9M guidance control sections (GCSs) provided from Fallbrook. [76]

AIM-9X Rollout Ceremony. A rollout ceremony was held May 1, 2002 at Raytheon Missile Systems in Tucson, Arizona, for the first production delivery of the next-generation Sidewinder Missile, AIM-9X. An AIM-9X Program Review was presented. [78]

AIM-9X IPT Received 2001 Daedalian Award. The NAVAIR AIM-9X Sidewinder Air-to-Air Missile IPT was selected to receive the Order of Daedalians' Weapons System Award for 2001. The AIM-9X program is a joint effort between the Navy and the Air Force. The team is made up of people from NAVAIR Patuxent River, Maryland; NAVAIR WD China Lake, California; Eglin AFB, Florida; Warner-Robbins AFB, Georgia; and Raytheon Missile Systems, Arizona. The AIM-9X is a fifth-generation IR, highly maneuverable missile that incorporates a high off-boresight capability that can be coupled with a helmet-mounted cueing system. Components were tested extensively on the five-axis flight table in the IBAR until the flyout was performed as expected. The Navy made its first shot at NAVAIR China Lake. The Order of Daedalians, a fraternal organization of military pilots, presents this award every year to organizations that have contributed the most outstanding weapons systems to the aerospace environment. [77]

Aviation Programs Update. Raytheon delivered the first production AIM-9X, marking the beginning of a projected 18-year production of the revolutionary missile. "Air-to-air tactics as they exist today will no longer be the same," said then CAPT David Venlet, the Naval Air Systems Command's program manager for air-to-air missile systems. "This is an advanced system design, which provides the warfighter with the firepower to ensure air superiority against any threat that exists today." The Naval Air Systems Command's AIM-9X Sidewinder Air-to-Air Missile IPT has been selected to receive the Order of Daedalians' Weapon System Award for 2001.

Strike Fighter Squadron 115—the Navy's first F/A-18E Super Hornet Squadron—is deploying with JSOW. CAPT Robert O. Wirt Jr., the Navy's program manager for conventional strike weapons, praised the performance and flexibility of the JSOW, saying that 45 percent of the 87 AGM-154A JSOWs used in Operation Southern Watch over Iraq were reprogrammed in flight by the pilot. Eleven JSOWs were launched against targets in Kosovo during Operation Allied Force. The weapon also has been used against enemy targets in Afghanistan in Operation Enduring Freedom.

Northrop Grumman RQ-8A Fire Scout: The third prototype of the RQ-8A Fire Scout unmanned aerial vehicle (UAV) was delivered to China Lake, California, for flight testing. [78]

Sidewinder Turns 50. Fifty years ago, a small innovative team, headed by Dr. Bill McLean, decided an air-to-air missile could be guided accurately using infrared radiation from the target. That was the birth of the Sidewinder missile at China Lake. Ceremonies celebrating the anniversary took place there in November 2002. [79]

Spike

Marines and Navy Seals Show Interest in Backpack Missiles. Navy engineers have designed a small, low-cost guided missile that would fit in a backpack. The candidates for this weapon are U.S. Marines and Navy Seal commandos. The missile also could be launched from unmanned airplanes. The fire-and-forget missile, called Spike, has been in development for three years at China Lake, California. The Spike system consists of a four-pound guided missile and a five-pound launcher. A Marine fire team should be able to carry a minimum of six rounds, according to weapon designer Steve Felix. The missile is expected to have a two-mile range. For Marines, the most important consideration is ease of use under stressful combat conditions. They want a weapon that will be "easy to use when you fear for your life," he said. Felix has shown the system to more than 1,000 enlisted Marines. "Once they get over the shock of being asked, they will tell you precisely what is wrong with your design. We designed Spike to hit lower-end targets, with little or no armor, so you can save the high-end weapons for the so-called high-value

targets," he said. The Navy and the Coast Guard, meanwhile, have shown interest in Spike as a ship self-defense weapon. [80]

A Small Missile for 'Soft' Targets. Spike may lack the sophistication of a Stinger or the Javelin shoulder-fired missiles, but it has more than enough fire-power to take out unarmored troop carriers and similar "soft" targets. The shooter aims the five-pound launcher and presses the fire button. A guidance system can put the four-pound missile on a target as small as two feet across. Marines and SEALs who have tested the $4,000 missile like the fact that its two-mile range keeps them beyond the reach of rifles. Spike's developers at the Naval Air Warfare Center at China Lake say the little missile could be ready for combat in about three years. [81]

Navy Plans to Adapt Spike Missile to Unmanned Aerial Vehicles. Spike may be adapted for use on unmanned aerial vehicles. The system is envisioned as a safer, more accurate alternative to rocket-propelled grenades (RPGs) and as a relatively inexpensive complement to the man-portable Javelin anti-tank missile. Compared to unguided RPGs with a range of only a few hundred yards, Spike will be guided and have a range of about two miles. A Javelin missile costs about $75,000; a Spike missile is expected to cost only about $4,000. The Javelin launcher costs about $125,000; the Spike launcher's estimated cost is $6,000. Spike, which will be light and easy to fit into a backpack, will have urban-warfare applications because the missile will be able to go through a window before exploding. Although Javelin is capable of destroying such soft targets, it makes more sense to use a lower-cost missile for that purpose and save Javelin for heavily armored targets, according to Spike program representatives, who displayed their system at a technology demonstration on Capitol Hill. "You don't really want to shoot $75,000 missiles at Jeeps," said Steven Felix, the project manager for Spike. Spike is expected to move into the system development and demonstration (SDD) phase near the end of calendar 2003 and enter production within about two or three years. Spike also could serve as a low-cost complement to the Hellfire air-to-ground, anti-tank missile, another relatively expensive weapon that has been successfully fired in combat from Predator UAVs. [82]

Weapon Platform Integration

Advanced Short-Range Air-to-Air Missile (ASRAAM) First Guided Flight

The first guided flight of ASRAAM on a U.S. Navy F/A-18 took place on February 27, 2002, at the China Lake Test Range. The live flight was successful, with the missile acquiring, tracking, and intercepting the BQM-74E sub-scale target as expected. The ASRAAM is a fourth-generation heat-seeking missile built by the U.K. It brings a wide range of capabilities to the Hornet. The challenge was to bring three countries together with different terminology, different time zones, and different capabilities to accomplish a common goal. The ASRAAM is being integrated on the F/A-18 aircraft for the Royal Australian Air Force (RAAF) under a FMS agreement with the U.S. Navy. "It has been a credit to all parties involved to work together," said Paul Butler of the RAAF, program manager for AIR-5400. [83]

AV-8B

AV-8B Passes Another Milestone—Launch Shows Off Joint Direct Attack Munition's (JDAM's) Inertial Navigational Unit. Another major milestone for the AV-8B Harrier program was reached on Friday, May 3, 2002. United States Marine Corps (USMC) Major Mark Brewster successfully released a GPS guided 1,000-pound (Mk 83) JDAM from a radar variant AV-8B. The JDAM was used to attack Damsville 21J, a simulated bridge constructed of sea containers, at the NAVAIR Land Range at China Lake. [54]

Joint Direct Attack Munition (JDAM) Flew 7.5 Miles and Hit Right on Target. The weapon was released from an altitude of 20,000 feet above sea level and flew for 67 seconds, almost 7.5 miles, before impacting the target. [54]

Demonstrated JDAM/Harrier Integration Using Open System Core Avionics Requirement (OSCAR) The primary test objective was to successfully demonstrate the integration of the JDAM onto the Harrier with the AV-8B OSCAR operational flight program (OFP). The launch successfully demonstrated the alignment of JDAM's inertial navigational unit with the inertial system on the Harrier and the transfer of the targeting data from the aircraft to the JDAM. [54]

Open System Core Avionics Requirement (OSCAR) is One of the First Naval Tactical Software Programs Using Commercial Standards. NAVAIR teamed with McDonnell Douglas Corporation, a subsidiary of Boeing Company, to develop the OSCAR Block Upgrade. Early Fleet introduction to Spanish and Italian squadrons is planned for this summer. USMC Fleet introduction is planned for Fall 2003. [54]

AV-8Bs Joint System Support Activity (JSSA) Soars to Level 4. OFP and Mission Planning Projects Give JSSA High Software Rating. After a 17-day Carnegie Mellon University Software Capability Maturity Model assessment, NAVAIR's AV-8B JSSA learned that its software capability has achieved a SEI Level 4 rating, out of a possible five. The team's rating puts it in the top 9% of the 1,800 government and industry software teams that have been assessed since 1987. Of that number, fewer than 5% are government organizations. The AV-8B JSSA started on the software road to excellence in April 2000 when it stood up the Systems/Software Engineering Process Group. Now, only two and a half years later, AV-8B has accomplished more than the team dreamed possible. According to SEI statistics, it takes six years, on the average, to go from Level 1 to Level 4. [54]

F/A-18

Finns: Advanced Weapons Laboratory (AWL) is 'Best Place' to Learn System Integration. The AWL integrates weapons systems on the F/A-18 Hornet and Super Hornet for the U.S. Navy and Marines and foreign military customers like the Australians, Swiss, and Finns. More than two years ago, the Finnish Air Force (FAF) planned to build its own System Test Integration Center (STIC), with the help of the Finn F/A-18 Program Office, PMA-265 and Boeing. The Finns visited integration facilities at Boeing in the U.S., Australia, and Switzerland before deciding to learn the software integration business from the AWL at China Lake. "We just picked the best place that has the most experienced and the most talented organization," said Harri Tilvis, team lead. "This was a sole-source request based on our long-term experience working with China Lake. It would take 10 managers and more than 30 software engineers to bring it all together," according to Kristy Fava, software configuration set (SCS) coordinator. The result is a program that includes one week of program management, three weeks of SCS development, five weeks of system test integration, all hands-on working with actual test cases in AWL's high-tech laboratories. [54]

F-14

Upgrade F-14B Advanced OFP. WD personnel were dispatched to the Fleet to brief an advanced training release of software and to install associated hardware in a F-14B aircraft. Eighteen aircraft were modified and crews were briefed on the OFP capabilities. Eighteen sorties were also briefed, monitored, and debriefed. [76]

F-14D Successfully Drops JDAM on Land Range During DT Phase. Two 2000-pound JDAM were released from a F-14D with tactical tape D04. The targets were a simulated bridge constructed of vertical and horizontal conex boxes, affectionately referred to as "Stonehenge," and a wooden constructed shack. Both JDAMs were released from 7.5 nautical miles away (ground range) at an altitude of 35,000 feet and hit with precision accuracy. [84]

Integrated F-14/JDAM. Integration of JDAM functionality into F-14B is complete. The NAVAIR Point Mugu engineering team accomplished final aircraft modifications while the Fleet squadrons were deployed at NSWC Fallon for airwing training. Two flight test engineers provided the squadrons with real-time mission planning and technical knowledge support. [76]

F-14D

Shared Reconnaissance Pod (SHARP) Tests 'All-Weather' Pod. F-14D integrated product team (IPT) and VX-30 team to test new radar. The Navy requested that a tactical reconnaissance and precision targeting synthetic aperture radar (SAR) be integrated into the SHARP system to enhance F/A-18 targeting capability. The SHARP pod, which provides electro-optical and infrared imagery, is used on the Hornet to help locate and identify targets. Adding SAR to the system would provide a new through-weather capability giving the warfighter a valuable, all-weather asset to accurately put weapons on target. The SHARP/SAR Program flight tested the pod using an F-14D Tomcat as a test bed. Raytheon made the technical modifications to the pod, and the F-14 IPT provided the contractors with an aircraft test platform and a viable test program. VX-30 conducted the tests. [54]

F/A-18

Delivered $120 Million F/A-18 Software Block Upgrade with More Than 100 Requirements. CrossTalk—the prestigious *Journal of Defense Software Engineering*—named the F/A-18 AWL and Boeing team among its top five government software groups, noting that the F/A-18 AWL team delivers improved warfighting capabilities to the Fleet. The selection was based on a major software block upgrade, the 15C SCS delivered to VX-9, the operational testers. This was a $120 million effort that incorporated more than 100 requirements including the JSOW, the AIM-9X Sidewinder, the Joint Helmet Mounted Cueing System (JHMCS), the Multifunctional Information Distribution System, the Digital Communication System, and the requirements from six FMS customers. [54]

U.S. Navy Introduces New F/A-18 Sensors. U.S. Naval Air Systems Command (NAVAIR) is "very happy" with the F/A-18 as a platform, according to program manager Captain Jeff Wieringa, but "we are lacking in the area of sensors. We are now working to bring the two aspects back into balance." NAVAIR plans to award Boeing a contract to conduct the system development and demonstration phase of the Hornet Autonomous Real-Time Targeting (HART) program, which will run from March 2003 to September 2007. HART will permit precision targeting of the Joint Direct Attack Munition (JDAM) from F/A-18C/Ds and F/A-18E/Fs, using AN/ASQ-228 Advanced Targeting FLIR imagery. As part of the HART effort, WD is supplying algorithms that it developed under the Direct Attack Munition Affordable Seeker (DAMASK) program for incorporation in Advanced Targeting FLIR. DAMASK added an imaging infrared seeker and new guidance algorithms to JDAM. The modified weapon conducted four successful engagements, following which WD received a two-year contract—now nearing completion—to "productionize" the design. WD is additionally working to make the seeker compliant with a request for proposals that Boeing has issued for a precision-guided weapon that could complement HART. [85]

Joint Helmet Mounted Cueing System (JHMCS)

JHMCS provides aircrews with a first-shot combat advantage in the air-to-air, within-visual-range arena. In the air-to-air role, aircrews will be able to cue and also verify the cueing of weapons and sensors to the limits of their off-boresight capability. Aircrews can exploit the full weapon and sensor envelopes in a dynamic close-in fight. In the air-to-ground role, this system will enhance lethality and survivability by reducing cockpit head-down and target-acquisition times. JHMCS incorporates a targeting display system mounted in a helmet to present look-through graphics projected onto the

helmet visor. During 2002, JHMCS completed operational evaluation. [83]

Multifunctional Information Distribution System (MIDS)

MIDS provides the F/A-18 with a secure, high-capacity, jam resistant, lightweight digital system for data and voice communications and navigation. Operationally, MIDS will provide the capability to interchange command and control, navigation, relative positioning, and voice and identification data among airborne, ground-based, and shipboard terminals. Multiple MIDS terminals can exchange data accurately and securely in near real time. In spring 2002, MIDS-equipped F/A-18s from both China Lake and Patuxent River successfully participated in the Joint Combined Interoperability Evaluation Team (JCIET) exercise at Eglin Air Force Base, Florida. This exercise demonstrated that MIDS is interoperable with the joint and international platforms present, and that the system could revolutionize cockpit situational awareness. [83]

Rapid Precision Targeting System (RPTS)

Tactical Dissemination Module (TDM) Gives Pilots an Edge. There's little margin for error in the cockpit of an F/A-18 flying a JDAM mission over enemy territory. Consider the sequence of events when the pilot receives a target tasking order, a series of numbers and letters designating the target's latitude, longitude and elevation—that must ultimately wind up in the mission computer. One wrong number and a miss is guaranteed. The solution to this error-prone procedure is the TDM. TDM is used to prepare a targeting package and then transmit it digitally into the cockpit of a strike aircraft. When the pilot accepts the mission, the target coordinates are entered directly into the smart munition, and the pilot sends a digital wilco message back to the controller. For aircraft with a data pod, the TDM can also transmit targeting information and images into the cockpit. TDM developmental work began at WD in 1993. The Navy's first system capable of transmitting target imagery into the cockpit was demonstrated by China Lake engineers during Operation Arid Hunter in 1994. Rapid Imagery Transmission to Aircraft (RITA) remarkably enhanced performance. Through the 1990s, development efforts were part of the RPTS project. [54]

Ready Missile Test Facility (RMTF)

Established RMTF. A few weeks after September 11, 2001, WD personnel loaded upgraded software into several SLAM-ERs that were then deployed aboard *USS John C. Stennis* (CVN 74), which was ordered immediately to the Persian Gulf in support of OEF. In early 2000, WD was tasked to convert several tactical surface-launched Harpoon missiles into instrumented rounds for the Combined Engagement Capability program managed from the Naval Surface Warfare Center Port Hueneme; successful upgrade and testing were performed on SLAM-ERs at the RMTF and on the Sea Range, and after the conclusion of these tests, SLAM-ERs were successfully launched in support of operations in Iraq. [71]

Interoperability/Battlespace Integration

EASTPAC LINK

Sea Range Part of Joint-Service EASTPAC LINK. A Sea Range operation exercised specialized communications capabilities of the *Constellation* Battlegroup in a joint-service environment. Participants included *USS Constellation,* the Aegis guided-missile cruiser *USS Chosin,* NAVAIR, and the Western Air Defense Sector (WADS) at McChord AFB, Washington. The exercise, EASTPAC LINK, tested the interoperability of several Tactical Digital Information Links (TADILs). These links are used to share "tracks"—information on the position, heading, speed and altitude of friendly, threat and unidentified contacts. The exercise also marked the debut of Point Mugu's Air Defense Systems Integrator (ADSI), which interfaces military and commercial radars, tactical data links and intelligence reporting systems. "In our case, it's real world," explained LCDR Sean Bergesen, the Joint Liaison Officer at WADS responsible for coordinating activities. "We're running 24/7, defending the North American continent and providing counter-drug surveillance. The more sensor coverage we have to build our air picture, the better we can do that job. The Fleet units and Point Mugu were great to work with. They are super professionals and have excellent equipment." Smooth functioning is key to successful joint operations, such as the peace-keeping activities in the Arabian Gulf region. By continuously updating position information for all platforms and potential threats, the Navy, Air Force, Marine and Army units stay apprised of the "big picture" and can make informed tactical decisions. [54]

Millennium Challenge 2002 (MC02)/Fleet Battle Experiment (FBE)-Juliet

Strike Warfare Command Center Created for MC02. More than 13,500 U.S. military and civilian personnel participated in MC02, a joint warfighting experiment at locations across the nation, including China Lake and Point Mugu. Sponsored by the United States Joint Forces Command (USJFCOM), the experiment brought together the four military services, U.S. Special Operations Command, and most functional/regional commands, as well as many WD and federal agencies. The purpose was to test experimental technologies and concepts in a simulated future-battlefield scenario. The Navy's role in MC02 was FBE-Juliet. MC02 and FBE-Juliet incorporated ground, air and sea capabilities among the services for mutual support and to achieve a common operational picture. In a China Lake laboratory, the Weapons Engagement Office built a Strike Warfare Command Center (STWC). This cell mimics a carrier command center bearing the call sign of Alpha Papa (AP). In addition to a staff of about 30 uniformed personnel manning the STWC, there were about 20 civilian technical representatives. Five people from the Weapons Engagement office worked with the experiment full time. The office also sent technical support to *USS Coronado*, the 3rd Fleet Command Ship. The conclusions of MC02 and FBE Juliet will give the USJFCOM valuable

information to analyze and discuss for use in future joint operations. [54]

Joint National Training Center (JNTC) Outgrowth of Fleet Battle Experiment (FBE)-Juliet/MC02. NAVAIR was a principal player in FBE-Juliet, conducted as part of MC02. MC02 was the largest joint experiment ever, featuring live field forces and computer simulations, and incorporating elements of all military services and special operations forces. NAVAIR performed two important roles in the FBE-Juliet/MC02 events. One was to provide the enormous military land, sea, and airspace and technical infrastructure to carry out real-world-sized combat operations. The second role encompassed an even larger area. WD and AD engineers linked six U.S. Western Ranges—Army, Navy, and Air Force—into a single network. Run from the Interoperability Test and Evaluation Complex (ITEC) at Point Mugu, the network carried voice, video, and tracking data to the Joint Exercise Control Group in Norfolk, Virginia. This interoperability demonstration was the precursor to the U.S. Joint Forces Command's Joint National Training Centers (JNTC) network, which will establish a global capability for distributed joint training and experimentation. Point Mugu's new OpCenter, slated to open in 2003, will host the JNTC Regional Center. [54]

Test and Evaluation/Range Support

Advanced Medium-Range Air-to-Air Missile (AMRAAM)

AMRAAM Team Sets Flight Test Data Record. Conducted Five Missions in Four Days Involving 14 Flights. The Navy AMRAAM test team conducted five successful missions in a row. The four-day test period involved 14 aircraft flights. During the flights, the AMRAAM test team gathered an unprecedented amount of data on the Sea Range using two F/A-18s detached from NWTS China Lake and one QF-4 from NWTS Point Mugu. Stuart Baker, the primary AMRAAM flight test engineer, said, "The testing ran smoother that any other testing I've seen in my 13-year career." The F/A-18s carried AMRAAM test vehicles that tested its latest versions against the ALQ-167 (electronic threat simulator) pods on the QF-4. New capabilities give pilots the ability to aim and fire several missiles simultaneously at multiple targets. The missile also allows the pilot to "fire and forget," letting the pilot perform evasive maneuvers as the missiles guide themselves into the targets. [54]

Now Operational on Multiple Platforms. AMRAAM is operational on the F-15, F-16, F/A-18, the German F-4F, the U.K.'s Sea Harrier, and the Norwegian advanced surface-to-air missile (SAM) system. The AMRAAM is currently being integrated on the F-22, the Eurofighter, JAS-39 Grippen, JA-37 Viggen, Harrier II Plus, Tornado, and HAWK-AMRAAM and high-mobility multipurpose wheeled vehicle (HMMWV) Surface Launch Systems. The AMRAAM Captive Equipment (ACE) and Integration Test Vehicle (ITV) pods were flown on the F/A-18s to test the missile's interface with the aircraft and missile guidance algorithms. The ACE pod contains AMRAAM radar and guidance systems that execute pre-launch, launch, and flight functions, allowing the integrated program team to test the capabilities of the missile and aircraft-missile integration in a wide variety of conditions and scenarios without ever having to actually fire the weapon. [54]

Sea Range Attracts British Royal Navy. British Naval Fighter Squadron 801 used the Sea Range at Point Mugu and the Land Range at China Lake to test the AIM-120B AMRAAM on their F/A-2 Sea Harrier aircraft. "We're evaluating the weapon with the Harrier, making sure it works as we expect it to. From there, we can develop new tactics for use in an operational situation," said British CDR Jon "Chips" Lawler, commanding officer. The squadron visits the United States. "Because the missile we're testing has such a long range, we needed to come here to find a range large enough," said Lawler. Missiles are fired over the Sea Range at drone targets launched from San Nicolas Island. Squadron 801 is just one of several international military units that use NAVAIR's Land and Sea Range every year, testing everything from weapons to guidance systems. "There's always value in joint training," said Lawler. "If the U.K. and U.S. go to war against a common enemy, it is advantageous to understand each other's methods of operation." [54]

Apache

Apache Helos Strike Deep on Land Range. They attacked after dark, a dozen AH-64 Apaches coming in from the south. Flying with their lights off, the helicopters were invisible in the moonless night. The first hint of trouble came when the lead Apache detected the signal of an SA-8 surface-to-air missile system. The pilot took evasive action, and the other aircrews began to put countermeasures into play. This was an exercise on the Land and Electronic Combat Ranges by the Army's XVIII Airborne Corps and the 229th Aviation Group. Staged from the Naval Training Center (NTC) at Fort Irwin, the mission was the first extended-range deep attack ever conducted in the U.S. In the days prior, flatbed trucks from Fort Irwin hauled 150 vehicle hulks into Etcheron Valley on the Land Range. NTC military personnel put the targets in place. The hulks were arrayed to simulate an enemy convoy of long-range artillery pieces. Then specialists rigged the targets with laser and radio receivers as well as flash units and smoke dispensers. WD provided radar operations, air control, microwave links, IR camera and GPS support, communications, computing, recording, crash-crews and range support. "These people were wonderful to work with," said MAJ Steve Baird, chief of NTC's Live Fire Division. [54]

Evolved SeaSparrow Missile (ESSM)

ESSM Launches Successfully at White Sands Ranges. The coordinated efforts of NAVAIR White Sands, Fokker Special Products, Raytheon, and National Range personnel resulted in a successful launch of the ESSM from the developmental Dual Pack 48 launcher system. On hand to observe the test were representatives of the Royal Danish Navy who are currently

the primary DP 48 customer of Raytheon Electronic Systems of Sudbury, Massachusetts. The system was designed to provide a lightweight, high-firepower alternative to systems currently in use on larger warships. Tests were conducted under the sponsorship of NAVAIR White Sands with a commercial services agreement with Raytheon. This was the first commercial business agreement between the two organizations and the National Range. The testing was accomplished in less than three months on an extremely limited budget. Mark Morgan, Raytheon Navy Test Manager, may have expressed it best: "This is a fine example of what a small and agile test team can accomplish in a short period of time with limited funding when they work together." [54]

F-22

Navy Involved in F-22 Program. NAVAIR is playing a significant role in the development of the Air Force's newest and most technologically advanced aircraft, the F-22. "The West Coast facilities are integrated and we're testing this platform in a joint manner," said Terry Haven, F-22 IPT lead at China Lake. Because the platform requires greater airspace to safely release guided missiles, the Air Force has decided to focus its testing on the West Coast. WD provides the resources to perform a full spectrum of test and evaluation, especially weapons separation testing. According to Michael Keeter, deputy F-22 IPT lead for T&E, "We've already accomplished four Sidewinder and four AMRAAM separations." NAVAIR is acting as the primary agent for the integration of the AIM-9M on the platform of the F-22 and will become involved in electronic warfare and systems effectiveness. An extensive IR signature evaluation, one of the largest of its kind ever performed, was completed at the Radar Reflectivity Laboratory (RRL), Point Mugu. A high point of the T&E program was the first guided AMRAAM shot from the F-22 performed on the Sea Range. The data links between Point Mugu and Edwards enabled Combined Test Force members to see the test develop in real time. "This is the biggest program in the Air Force and they trust us enough to do the test here," Haven said. [54]

General Purpose Bombs

Joint Improved Bomb Fin Project Leads the Way for Second Generation of Mk 82 High-Drag Bomb Fin. Henry Patterson of WD's In-Service Engineering Branch for Strike Weapons initiated the second phase of the Joint Improved Mk 82 Series (JIMS) Bomb Fin Project to bring together resources of United States services and NATO countries that are members of the Mk 82 Weapons Community. The Naval Mine Warfare Activity, Marine Corps, Air Force and NATO country armed services had the opportunity to participate in the test, evaluation, and fielding of the improved bomb fin. Benefits included increased stability in the low-drag, high-speed release mode and increased compatibly with flight delivery requirements of modern attack fighter/fixed-wing aircraft. The JIMS Bomb Fin availability, at approximately one-third the cost of the mechanically designed BSU-86/B Bomb Fin, makes it possible for the Air Force and Navy to share production costs, with both BSU-49/B and JIMS Bomb Fin produced on the same production line. "The JIMS Bomb Fin has potential to be the best alternative over the next 15 years for Mk 82 Bomb high-drag function," Patterson said. [54]

Harpoon

Successfully Demonstrated Block II Missile in Test Flight. Demonstrated Open-Ocean Ability to Select Proper Targets Using the Mobile Ship Target (MST). June 2001 marked the first launch of the missile upgrade at Point Mugu. The objective was to demonstrate the Harpoon Block II weapon system open ocean ability to select the proper target using the USN's MST and another target ship, the Mk 35 seaborne powered target (SEPTAR). "Harpoon Block II is a prime example, during austere budgets, of the positive aspects of modernizing an existing weapon to give a warfighter drastic improvements," said the Navy's Standoff Missiles Program manager. Harpoon Block II provides accurate long-range guidance for coastal and ship targets by incorporating the low cost IMU from the JDAM program and the software, mission computer, integrated GPS/INS, and GPS antenna and receiver from the SLAM-ER. Harpoon Block II is capable of executing both anti-ship missions and coastal target suppression. The blast warhead delivers lethal firepower against a wide variety of land-based targets, including coastal defense sites, SAM sites, exposed aircraft, port/industrial facilities, and ships in port. These Block II improvements will maintain Harpoon's high hit probability, even against ships very close to land and in congested waterways. [54]

Hellfire

VX-9 Finishes Hellfire Quick Reaction Testing in Record Time. **China Lake Performed in Four Weeks What Could Have Taken Four Months.** Major Brendan Reilly's enthusiasm is contagious. Extremely excited about his latest efforts to help VX-9 and the Navy and Marine Hellfire II project, the Marine Major was happily showing off his AH-1W Cobra helicopter, loaded with Hellfire missiles, to local media on the evening of August 9, 2001. Reilly is VX-9's OT director. Air T&E Squadron Nine, out of China Lake, performed in four weeks what could have taken four months—or four years—to do. "This is a real 'VX-9-does-good story,'" Reilly said. [54]

Successful Hellfire Scores Three Out of Three Hits. VX-9 fired three Hellfire "mikes" and two "kilos" on the China Lake Land Range, hitting their targets successfully. The purpose of a QRA is to provide a preliminary look at what capabilities and limitations the AGM-114M warhead may provide. According to Major Brenden Reilly, VX-9's Operational Test Director, "This is important because when we put Marines out there on a deck—Hellfire protects them. This is why VX-9 is here—to make sure the warfighter is supported with effective and suitable equipment." [54]

High-Speed Antiradiation Missile (HARM)

Italian Air Force Generals Visit the Lake. The Italian Air Force arrived at China Lake with 110 people and four Tornado jets for a three-month deployment. They were here to run an advanced training campaign for the AGM-88B HARM Program. "The China Lake range was selected because of the vast flying space, specific simulators and technical capabilities," said COL Pino Scancarello of the Italian Air Force staff. LTGEN Pasquale Garribba, commander Air Combat Command, flew over the ECR in a Tornado aircraft. Garribba said he was pleased with the support his troops have received from WD. "We are grateful to this community. They have accepted us in a very warm way. We are flying our Tornados with the HARM at the ECR. Everyone knows that China Lake is the home of the HARM. China Lake, in my opinion, is the most unique range in the world for testing weapon systems." [54]

High-Speed Maneuvering Surface Target (HSMST)

Aegis Test is Success at Atlantic Fleet Weapons Test Facility (AFWTF). Point Mugu provided technical and operational support for a multi-axis HSMST test against an Aegis destroyer, DDG-84, *USS Bulkeley*. The Surface Targets personnel provided oversight and hands-on support in the installation and checkout of the onboard control systems aboard the vessels. These systems were critical to the successful control of multiple targets. In addition, they operated the vessels from Command Center, and a contingent was at sea to troubleshoot any problems that arose during the operations. The Aegis system is a total ship-borne detection-to-kill weapon system. The heart of the Aegis system is the AN/SPY-1 phased-array radar. A computer-based command and decision element makes the Aegis combat system capable of simultaneous operation against antiair, antisurface, and antisubmarine threats. The HSMST test was performed on the AFWTF in Puerto Rico. Following the multiple threat depth-of-fire event, a Standard Missile (SM-2 Blk III) was tested against one of the HSMST targets. "This missile firing was the first test against this type of surface target," said Aegis Test and Evaluation Associate Richard Meiners. "This was the first time six HSMSTs were simultaneously controlled via the Integrated Target Control System (ITCS) at a maximum range (70 nautical miles) from a test range facility. Using combat direction finders, an armed helicopter equipped with the Hellfire missile, a simulated standard missile (SM-2), a 5-inch gun, and the Phalanx weapon system, the ship performed with excellence and met all test objectives," Meiners said. [54]

Joint Standoff Weapon (JSOW)

Demonstrated Successive Multiple Launch Capability to Two Different Targets. The Land Range supported the Air Force initiative to integrate JSOW into B-52s. The B-52 launched two weapons three seconds apart on two close but separate targets on the Land Range. Release was nominal, with both weapons dispensing and hitting their targets. The JSOWs flew exactly as planned, gliding to their targets for five minutes. Objectives of this developmental test were to finalize B-52 and JSOW integration and to demonstrate successive multiple-launch capability to two different targets. With B-52 integration complete, JSOWs will soon be delivered to B-52 bases for operational use. The NAVAIR JSOW program manager emphasized that this was truly a significant accomplishment for the overall program. JSOW, built by Raytheon Missile Systems, Tucson, Arizona, has revolutionized strike warfare by providing a low observable glide weapon that ensures warfighter survivability by enabling precision air strike launches from beyond most enemy air defenses. [54]

Successful JSOW Launch From a B-52. An Air Force B-52 successfully launched two AGM-154A JSOWs on February 8, 2002 on the WD test ranges. The B-52H bomber from the 419th Flight Test Squadron, 412th Test Wing, Edwards AFB, performed the dual launch with two full-rate production JSOW-As from 35,000 feet at 0.8 Mach. This test successfully completed the DT efforts on the B-52 with the simultaneous launch of these two weapons from a shoulder station and a centerline station on the B-52H utilizing a generated mission planning data load. [54]

Successfully Demonstrated JSOW Unitary Warhead. Weapon Flew 32 Miles to Score a Hit. A NAVAIR Navy Test Team and its industry partner, Raytheon, marked another important milestone for the JSOW program. The flight team successfully completed a second free-flight demonstration of the JSOW Unitary warhead variant using waypoint navigation and autonomous target acquisition capability in the AGM-154C. An F/A-18C/D pilot released the AGM-154C while flying at 29,000 feet and 0.9 Mach over the WD test ranges. The weapon then navigated autonomously through several en-route waypoints to begin searching for the target approximately 32 miles from the launch point. Aircraft separation, flyout navigation followed by target acquisition, and subsequent impact were completed as predicted. "The successful completion of this flight is a tribute to this Government/Industry Test Team. The teamwork and cooperation displayed by Raytheon, the NAVAIR program office, the test team at Point Mugu, and the range control team at China Lake brought this success exactly as predicted," according to the Raytheon JSOW program director. [54]

Laser-Guided Bomb (LGB)

Second-Source Qualified for LGBs. Flight tests at NAVAIR WD were completed, qualifying Lockheed Martin as a second-source supplier for advanced LGBs. Tests included dropping four 500-pound GBU-12 LGBs. Overall the test program included 60 tests. This brings a second supplier on board at a time of high-production requirements to support the war on terrorism. [87]

Miniature Air-Launched Decoy (MALD)

USAF Eyes Decoy, Jammer as Miniature Air-Launched Interceptor (MALI) Demonstration Ends. The Defense Department is preparing to develop a new air-launched decoy to spoof enemy air defenses. Development plans call for a

several-year-long system design and demonstration phase for the MALD. Potential bidders can leverage work undertaken during the supersonic MALI program, which ended with a November 26, 2002, flight test at China Lake. During the mission, the vehicle performed its first supersonic flight, reaching Mach 1.1, according to Art Lofton, director of operations and plans for advanced systems at Northrop Grumman. MALI was launched from an F-4 flying at 20,000 feet above sea level. It flew for 11.5 minutes, operating for several minutes at supersonic speeds. The air vehicle executed nine waypoints and completed a northeast to southwest racetrack on Echo Range at China Lake. [88]

Pegasus

Pegasus to Continue Testing. Northrop Grumman's X-47A Pegasus experimental aircraft completed initial low-speed taxi tests at China Lake's airfield. Pegasus flies with no pilot on board. It is an UAV, the prototype for a Navy UCAV-N designed to operate from the deck of an aircraft carrier. Northrop Grumman is the prime contractor for both the Global Hawk reconnaissance system and the Fire Scout vertical takeoff and landing tactical UAV—which also made its first flight at China Lake. Pegasus' first baby steps took place on Runway 26 with a straight-line, 20-foot taxi at three knots. Some of the landings will employ the Navy's newest carrier-landing system, the Shipboard Relative GPS, which was designed by NAVAIR engineers at Patuxent River. [54]

First Flight for Pegasus. Northrop Grumman's demonstrator unmanned combat aircraft has made its maiden flight at the China Lake. During its initial 12-minute sortie on February 23, the tailless, 27.9-foot-long, 27.8-foot wingspan, diamond-shaped X-47A Pegasus autonomously climbed about 1,200 feet, reached a speed of 150 knots and landed within 20 feet of a predetermined spot on the runway. "The first landing would be accurate enough to catch an arresting wire during a carrier landing," said David G. Mazur, the company's X-47 program manager. The team wanted to fly early in the day while the desert air was smooth, cool, and dense. "An initial review of the test data showed that performance and following the flight path went as planned," Mazur said. There were no warning or caution advisories that highlight problems on the aircraft. Throughout the flight, the navigation system of the aircraft maintained an accuracy of 0.3 meter horizontally and 0.5 meter vertically. "That tells us we knew the position of the airplane within 1.5 feet through most of the flight. Vertical accuracy was within a half meter," Mazur said. Post-flight, "There was no indication we had any problems," Mazur said. [89]

Rolling Airframe Missile (RAM)

Fleet RAM Tests Supported. The first open-ocean testing of a RAM aboard an amphibious ship was completed on April 3 by ships of the *Essex* Amphibious Readiness Group. This evolution followed RAM at-sea tests a week earlier aboard *USS Kitty Hawk*. *USS Essex* (LHD-2), *USS Germantown* (LSD 42), and *USS Fort McHenry* (LSD-43) all fired RAMs at target drones launched from the *Germantown*. A NAVAIR WD team supported the exercise. A WD-developed GPS Reporting Information Package System (GRIPS) was used track and monitor the ships and drone targets and for safety. Both the *Kitty Hawk* and *Essex* groups were highly pleased to be able to test the missiles at sea during their forward deployment, as it contributed to their readiness for a planned extended deployment. [87]

Standoff Land-Attack Missile–Expanded Response (SLAM-ER)

WD Supports Fleet SLAM-ER Training. On June 5, 2002, CVW-14 and CVW-2 F/A-18 aircraft from Lemoore, California conducted two successful launches of the SLAM-ER. The late afternoon strike, launched from Naval Air Station (NAS) Lemoore, scored direct hits on a simulated weapons truck depot in a tunnel target complex and on a simulated Square Pair radar located on Coso Peak at the WD Land Range. The rugged terrain surrounding the targets closely replicated the terrain of Afghanistan. This strike mission was the culmination of a rigorous training evolution for the Fleet aircrews provided by Strike Fighter Weapons School Pacific (SFWSP), Boeing, Naval Strike and Air Warfare Command (NSAWC) and the WD Point Mugu SLAM-ER Tiger Team. Training consisted of classroom briefings and simulation training at Boeing, hands-on tactics and scenario development with SFWSP and NSAWC, and numerous captive-carry flights. [87]

Sparrow

Expanding Sparrow Missile Emergency Inventory. WD Point Mugu has numerous Sparrow missiles in inventory with expired maintenance date due (MDD) dates. WD responded to an inquiry from the Weapons Test Squadron about testing the missiles to make them ready for emergency contingency operations. Subsequently the Navy item inventory manager announced plans to ship these assets back to the weapons depot. [76]

Conducted Sidewinder and Sparrow Missile Repairs on *USS John C. Stennis.* NAVAIR personnel provided *USS Stennis* (CVN-74) with non-critical parts, allowing them to locally repair two AIM-9s and three AIM-7s. This unquestionably saved the USN vital maintenance dollars in shipping and repair costs, but more importantly, allowed these combat assets to remain where they belong, "flying on combat missions." NAVAIR WD Sparrow Integrated Logistics Support (ILS) Team provided parts and maintenance procedures to *USS Stennis* to repair an additional eight AIM-7 Sparrow missiles. [76]

SSM-1

Japan Ground Self-Defense Force (JGSDF) Honors Matsuo in Japan. The JGSDF's senior-ranking general honored Anthony T. Matsuo, WD Surface-to-Ship Missile project manager, in a private ceremony at Japan Defense Agency Headquarters in Tokyo. In recognition of Matsuo's 10 years of service to Japan's SSM-1 missile program, Gen. Tsuneo Isoshima, Chief of Staff, presented Matsuo a

letter of appreciation. Matsuo accepted Gen. Isoshima's high praise on behalf of the WD team, explaining, "Over 250 personnel support the SSM-1 program at Point Mugu every year— consistently and professionally. Your kind words today honor them." [54]

Target Launches

Kodiak Island. NAVAIR supports Missile Defense Agency (MDA) target launches. The MDA requires that a DOD flight-safety authority certify and execute flight-safety responsibilities for missile launches at the Kodiak (Alaska) Launch Complex. Under a Memorandum of Agreement established in January 2003, WD is assigned these responsibilities for two MDA target launches at the Complex. These flights, conducted by the MDA's Long Range Targets Product Office, are scheduled for August and December 2003. WD will develop procedures and execute all missile flight-safety analyses and missile flight control on the day of launch. Additional flights may be added under this Memorandum of Agreement. [3]

Target Vehicles

MA-31 Target Vehicle Successfully Launched From an F-4D. Team MA-31, a group of skilled personnel from NAVAIR, Boeing, and British Aerospace (BAE) Flight Systems, successfully launched an MA-31 target vehicle on July 3 from an F-4D Phantom II aircraft. The exercise provided a supersonic sea-skimming target for *USS Constellation* Battle Group's surface-to-air missiles (SAMs). The MA-31 operation provided invaluable, realistic training for surface combatant defense systems, helping to prepare the battle group for its upcoming deployment. The MA-31 target vehicle can be released from a variety of altitudes, at which point a rocket booster ignites and accelerates the vehicle to supersonic speeds. Once the rocket motor is depleted, a ramjet engine sustains the vehicle in flight through various preprogrammed maneuvers. The launch was from 33,000 feet. The vehicle flew a glide profile to 5,000 feet, and the rocket booster ignited and flew it down to a sea-skimming altitude.[54]

Tomahawk

Tomahawk Launched in a 860-Mile Successful Test Flight. A Tomahawk cruise missile was launched in an operational test on March 12, 2002, from *USS Bremerton* (SSN-698), a submerged *Los Angeles*-class submarine off the southern California coast, on the Point Mugu Sea Range. Seconds after launch from the submarine's torpedo tube, the Tomahawk missile transitioned to cruise flight for the land-attack mission. It flew a fully guided 860-mile test flight, using terrain contour matching (TERCOM) navigation and continuously observed and tracked to a target and recovery site on the test range. The missile's parachute recovery system was activated as planned. The missile was safely recovered and will be refurbished for future use. [54]

Tomahawk Tracking/Monitoring. Point Mugu Bloodhounds Track Two Tomahawk Missiles. This exercise involved 12 aircraft, several ground stations, surface and subsurface assets. "It's like chasing a little 420-mph stick in the sky," explained an F-14 pilot for the NWTS Point Mugu Bloodhounds. He was referring to his experiences on 18 and April 19, when Point Mugu participated in two CNO-1 Tomahawk shots involving 12 aircraft and several ground stations, as well as surface and subsurface assets. [54]

WD Provided Chase Aircraft. **The missile's ability to outperform the aircraft requires constant vigilance on the part of the aircrew.** QF-4s, F-14s, and one NP-3D received and transmitted telemetry data. In the chase role, aircraft are required to have remote flight termination and the ability to control the vehicle remotely in heading, altitude, and speed, should problems arise. They do this by means of a cockpit control box and a pod carried on an external weapon station. The very complicated and highly intense chase role begins with aircraft intercepting the missile shortly after take-off. This often proves to be the most exciting phase of the flight, with closure rates of more than 1,000 mph with the missile and visual ranges less than one mile. While all this is going on, ground stations track every move the Tomahawk makes and record every bit of data for post-mission analysis. The NP-3D maintains a track to provide a vital telemetry relay to the other players for tracking of aircraft and missiles. This information is used for post-flight analysis and also to maintain safety-of-flight conditions for all involved. [54]

Conducted First Free Flight of Tactical Tomahawk (TACTOM) Block IV. The combined Navy/Raytheon TACTOM team successfully conducted testing on the Sea Range. After a one-day delay the missile was launched vertically from a ground test stand located on San Nicolas Island and transitioned to cruise flight, successfully demonstrating all pyrotechnic and control-surfaces deployment functionality. The missile flew a fully guided 550 miles using GPS and digital scene matching area correlation (DSMAC) navigation updates. Additionally, the TACTOM successfully demonstrated two new capabilities unique to this weapon system: in-flight retargeting and UHF satellite communications. The missile executed a flawless terminal dive maneuver and successfully impacted the intended target at San Clemente Island. [90]

TACTOM Takes Flight. The TACTOM, took flight at the Point Mugu Sea Range in California as part of the contractor test and evaluation phase. The missile launched vertically from a ground test stand and transitioned to cruise flight for the land-attack mission. The missile flew a fully guided flight and demonstrated two unique capabilities—in-flight retargeting and satellite communication. The TACTOM will boast several enhancements, including mission planning onboard the launch platform, in-flight retargeting, loiter and battle damage assessment capability and in-flight health and status reports. "It is a perfect example of industry and government teaming together to maximize taxpayer dollars by developing greater fire power with increasingly efficient technologies," said Navy CAPT Bob Novak, program manager. The Land Range deployed the entire TSPI (time, space, position information)

scoring team and a telemetry, communication, and power support team to San Clemente Island for a week of logistics, setup, and test support. Steve Eggers, NAVAIR Land Range test manager for Tomahawk, said, "We took an uninstrumented range and fully instrumented it with power, telemetry, photography, TSPI scoring, and communications within two days. It was a phenomenal effort by the entire NAVAIR civilian and contractor support team." [54]

TACTOM Soars Through Test Flight. The highest standard in warfare technology was demonstrated. The missile was launched vertically from a fixed underwater launcher and successfully demonstrated shroud separation, rocket motor firing/separation, and deployment of fins, inlet duct and wings. It flew a fully guided flight using GPS, terrain contour matching and DSMAC navigation updates, and demonstrated its GPS anti-jamming performance capability. The TACTOM impacted the target structure as planned. The Block IV is the latest variant of the Navy's premiere cruise missile. The Tomahawk is ship and submarine launched and was first employed operationally during Desert Storm. Since then, the missile has been heralded for its accuracy and lethality. "Tactical Tomahawk design is well on its way to providing the Fleet with the most technologically advanced land attack cruise missile ever built," said Navy CAPT Bob Novak, program manager. [54]

Tactical Tomahawk First Submarine Test Launch. The U.S. Navy's new Tomahawk cruise missile, the Block IV, or Tactical Tomahawk, soared through yet another first on July 9 when it was launched from *Los Angeles*-class submarine *USS Tucson* (SSN 770) at the Sea Range. The event marked the first launch of the Tactical Tomahawk from an operational submarine launch platform. The test demonstrated the newly developed Block IV Tactical Tomahawk Weapons Control System (TTWCS) and the Tomahawk Command and Control System functionality, allowing the launch platform to receive an operational Block IV mission, pass it to the missile, and then launch it from a submerged location. The missile flawlessly navigated the assigned mission through the use of a GPS and DSMAC updates. The Tactical Tomahawk will become operational in mid-2004. [91]

Electronic Warfare

EA-6B IPT Database and Mission Planning Support

Provided Fleet Training on Mission Planning. USMC and USN assets in the continental United States have requested and received visits from WD personnel to train them on advanced receiver operations and use of mission-planning update capability. [76]

Provided Round-the-Clock Threat Database Support Through the Electronic Warfare Database Support (EWDS) Laboratory. Support activity occurrences have numbered in the thousands during FY02, including Secret Internet Protocol Network (SIPRNET) email, rapid-reaction file updates, telephone calls, and fused intelligence database support. The EWDS team released the latest version of the Electronic Warfare Tactical Information Report Management Systems (ETIRMS) to the Fleet in September 2002. ETIRMS is a PC-based software application that puts a fused intelligence database, map, and mission-planning support at the user's fingertips. Fused intelligence is the result of using multiple separate national intelligence sources. The intelligence officer can make a more comprehensive conclusion about the enemy's disposition. Round-the-clock (24/7) support is necessary because deployed EA-6B squadrons are up against a continually changing electronic threat in a combat environment. For example, by the end of the day on September 11, 2001, the EWDS Laboratory had released an updated electronic order of battle (EOB) to the deployed EA-6B squadrons. In addition, the EWDS Laboratory exchanged more than 11,000 email inquiries during FY01 in support of Operation Enduring Freedom. [92]

Developed and Delivered Three Rapid-Reaction Files to update mission-planning tools with the latest threats/tactics in the area. Files were delivered to deployed EA-6B squadrons.[92]

Developed and Delivered Three Portable Flight-Planning System (PFPS) Threat File Updates. The updates are used to better synthesize data from multiple sources for aircrew evaluation. Updates were delivered to deployed EA-6B squadrons either by Secret Internet Protocol Network (SIPRNET) email or CD-ROM. The threat file updates contain the enemy's EOB, which consists of a radar or weapon system's location and operating parameters. The EOB is then displayed on the map feature of PFPS, which gives the aircrew superb situational awareness. [92]

Released Three Jammer Techniques Optimization (JATO) Technical Briefs on Jammer Effectiveness. The briefs delivered to deployed EA-6B squadrons included some new communications jamming capabilities via the new universal exciter upgrade (UEU) transmitter. The technical briefs were developed by the JATO team at Point Mugu through educated analysis and field testing. The UEU the "brains" of the ALQ-99 jamming pod carried by the EA-6B, produces the complex electronic signals that are used for electronic warfare jamming. [92]

Produced a Portable Flight-Planning System (PFPS) Electronic Order of Battle (EOB) File. This allowed Fleet users to look at located threats on their laptops. The threat file updates contain the enemy's Electronic EOB, which consists of a radar or weapon system's location and operating parameters. [92]

EA-6B Integrated Product Team (IPT)

EA-6B IPT Demonstrates Battlespace Management Technology with VAQ-135. Black Raven 503, from Electronic Attack Squadron (VAQ) 135, arrived at Point Mugu to demonstrate the EA-6B capability as a battlespace

manager. The EA-6B showcased its new data-link capability with an F/A-18, and VAQ-135 demonstrated a new commercial Fujitsu pentablet computer that will be installed in the cockpit—a powerful upgrade over the much larger and slower legacy laptop. The Point Mugu EA-6B team provided the computer, attached a ruggedized data cable/harness to it, integrated the software so it could communicate via the aircraft's data link, and then supported the system during Fleet Battle Experiment Juliet (FBE-J) in August 2002. [54]

EA-6B Releases Electronic Warfare Tactical Information and Report Management System (ETIRMS) 4.2. The Point Mugu EA-6B team developed and fielded ETIRMS for the Fleet. ETIRMS is an easy-to-use Windows-based software application that replaces a cumbersome, 4-foot-high stack of tactics manuals. ETIRMS makes all the known enemy weapon systems' operating parameters, pictures, tactics, diagrams, and technical data available and at the user's fingertips. Moreover, the team issued each squadron a new Dell laptop computer so that they will have a dedicated ETIRMS terminal. ETIRMS 4.2 includes a worldwide database for equipment locations plus characteristics and performance data on all platforms, weapons, emitters and communication systems. ETIRMS provides ambiguity analysis/identification cards, kneeboard cards and briefing materials. Data types include multi-source, National Security Agency's (NSA) electronic intelligence (ELINT) parameters list. This tool allows a user to filter the world's threats by country or countries. ETIRMS will greatly enhance EA-6B warfighters' effectiveness. [54]

EA-6B IPT Weapon System Software Support Activity (SSA)

Avionics Upgrade

Integrated a High-Speed Antiradiation Missile (HARM) Block VI Precision Navigation Upgrade (PNU) for the EA-6B. The Point Mugu team is serving as the key systems engineer for integrating the full capabilities of the weapon into the EA-6B's Operational Flight Program (OFP). The upgrade increases the weapon's performance capability through the addition of a GPS receiver, an IMU, and digital processor. By incorporating an improved geographic specificity algorithm, the missile's probability of hit will dramatically improve. In addition, the Point Mugu team has been working with the NSA to document the HARM PNU GPS key concept of operations (CONOPS). [92]

Developing and Integrating the Multifunctional Information Distribution System (MIDS) for the EA-6B. MIDS is a critical network centric, battlespace-management tool. MIDS is the Link-16 terminal selected for the EA-6B. Installation involved numerous systems, including replacing the Intercommunications System (ICS) with digital, and upgrading the mission computer. The Point Mugu team is developing the software and displays onboard the EA-6B that will make the MIDS data link work. The team is also fully integrating MIDS into the EA-6B weapon system's Operational Flight Program (OFP). [92]

Developed Software Loading Utility and Tactical Integration Concepts for the ALE-47 Counter Measures System (MS). Unlike the older stand-alone ALE-39 system, the ALE-47 system can be integrated with the EA-6B Tactical Jamming System for automatic or programmed use. The Point Mugu team is developing the OFP, which integrates the ALE-47 with the rest of the aircraft's weapon system. The new OFP will enable the EA-6B to communicate and control the ALE-47 through the main weapon system interface [92]

Conducting the Second Embedded Global Positioning System (GPS)/Inertial Navigation System (INS) (EGI) Program. This program replaces the ASN-130 Carrier Aircraft Inertial Navigation System (CAINS) in all Block 89A and ICAP III (Improved Capability III) EA-6B aircraft. This will reduce Fleet aviation depot-level repairable-maintenance work hours and training costs by approximately $20 million annually. The Point Mugu team is acting as Systems Engineer for integrating the second EGI into the current avionics architecture and installing it on Fleet EA-6Bs. [92]

Developed Fiber Optic Network (FON). The FON is for off-the-shelf fiber-optic components used in the Department of the Navy (DON) aircraft. The replacement of conventional cable in the aircraft will increase reliability, capacity, and survivability while reducing weight and maintenance costs. The Point Mugu team is acting as systems engineer for integrating and designing the FON into the existing avionics architecture. [92]

Completed Modifications for the Data Storage Memory Unit (DMSU). The digital DMSU replaces the cumbersome Recorder Reproducer Set that is currently used. The Point Mugu team is acting as systems engineer for integrating the DSMU into the current avionics architecture. [92]

High-Speed Antiradiation Missile (HARM), F/A-18

Released HARM Software. Electronic Intelligence (ELINT) 570 software was released to forward-deployed squadrons. The package contained ELINT PC-Cards, ELINT data in soft and hard copies, the HARM mission planning module (MPM) update compact disk, and instructions. One package was shipped to each F/A-18 squadron on three aircraft carriers. The Software makes HARM effective against new threat radars. [95]

EA-6B Operational Flight Program (OFP)

Developed New OFPs. For Block 89 and 89A aircraft, SSA-5.3 (builds 5,6, and 7) and SSA-2.0 builds have been developed and provided for developmental test. These include increased jammer management and new HARM VI capabilities. These releases are the culmination of extensive Fleet interface through a comprehensive review board process and technical excellence in software development. [92]

Provided Critical Support for the USQ-113 SSA for This Communications Jamming System. Support included

developing software, storage, and recorded data-transfer upgrades, and the improved operator control panel (IOCP). [92]

Radar

Accelerated Periscope Radar Development. A letter contract was issued on January 23, 2002 for antenna development for the Periscope Radar Program to accelerate procurement of this new system that will assist in the war on terrorism. The system being developed by these contracting actions is required for submarine safety and Special Forces support when operating in littoral waters. While normal development was under way to increase safety of mission and situational awareness, the requirement has become an urgent top priority because of the war on terrorism. [76]

Electronic Jammer Techniques Optimized for Fleet EA-6B Operations in War on Terrorism. In response to time-critical Fleet SIPRNET requests, two JTAT (Jammer Technique Analysis and Tactics) documents were prepared on August 2, 2002. The JTAT is an operator's how-to guide to most effectively employ the EA-6B weapon system against a specific threat in a specific theater. The JTAT is a direct tester-to-operator conduit and one of the most valuable products from the JATO Laboratory/EWDS team at NAVAIR Point Mugu. Team efforts directly support strike operations in the war against terrorism. [87]

Provided Fleet Training on Radar Cross Section. The Aegis Program Lead Test Engineer responded to multiple inquiries regarding radar cross section and physical characteristics of relevant threat targets and electronic attack capabilities and techniques employed. [76]

SA-8

SA-8 is the Real Thing; Electronic Combat Range (ECR) is Home to the Air Defense Missile System. The SA-8 is deployed in numerous countries around the world. It can also be found in the washes of China Lake's ECR. The SA-8 is a sturdy weapon. The entire system—radars, missile launchers, and fire-control systems—rides on a go-anywhere amphibious vehicle. A 300-horsepower diesel engine powers the six-wheel-drive system and dual propellers. "Our operators are good," said Steve Davis, crew chief for the team. "If the pilots can fly against us without getting shot down, they have a good chance of survival when they go into combat." Minimal documentation is available and the schematics are drawn in Russian electronics symbology and annotated in Cyrillic letters, so in trouble-shooting, ECR technicians resort to a lot of reverse engineering. When U.S. Army forces carried out a deep-penetration attack on the ECR, an Army general watched as one of his Comanche helicopters was "shot down" by an SA-8—tracked continuously for the amount of time it would take for a missile to be launched and fly to the target. He commented, "My crews have got to see this video so they don't make that mistake again." F/A-18 pilot LCDR Dave "Manny" Ramsey is impressed: "Operators overseas are mostly 18 to 22 years old with relatively few years experience. But these guys at the ECR have been living in that box for years. They are, no kidding, the best in the world." [54]

TACAIR EW

Electronic Warfare (EW) Suite

New EW Suite for TACAIR. Delivered updated EW Suite for TACAIR to operational test (OT). Updates include a new higher-order language (HOL) OFP and User Data File (UDF) for the ALR-67(V)2 radar warning receiver (RWR), OFP and UDF update for the ALQ-165 RF jammer, and Mission Data File (MDF) update for the ALE-47 dispenser. [54]

ALR-67(V)3

Enhanced Supportability and Performance of the ALR-67(V)3. The ALR-67(V)3 program at WD responded to a drill that addressed accelerating the program from a supportability and performance standpoint. The goal of this drill was to identify specific actions that can be taken to improve warfighting capability in the near term. [54]

AN/ALE-56

Integrated AN/ALE-56 Countermeasures Dispensing Pod on AH-1W. The Mongoose countermeasure dispensing pod is currently in use on F/A-18 test aircraft and on U.S. Navy and Air Force QF-4 drones. This system significantly augments existing countermeasure capabilities, with minimal operational effort or down time. It offers operational planners and unit commanders greater offensive flexibility by allowing airborne assets to operate with greater autonomy, for longer periods of time, in extremely hostile environments. WD integrated this capability on the AH-1W Supercobra for potential use in Operation Enduring Freedom. Additionally, the U.S. Air Force integrated this system on a C-130 aircraft for technology demonstration and proof of concept. Currently WD is developing the next-generation Mongoose Pod that will offer a greater variety and quantity of expendables and will have direct applicability to the H-60 aircraft. [96]

Weapon System Upgrade

Developed the EA-6B State-of-the-Art ICAP III. Currently in Developmental Test. ICAP III incorporates numerous weapon system enhancements that will meet and exceed current threat capabilities and will ensure the lowest possible attrition and highest effectiveness. The Point Mugu team developed the software and integrated the highly sophisticated hardware that makes up the ICAP III system and developed the concept for keyboard controls and display schemes. [92]

Energetics

MILCON

MILCON P-453 Groundbreaking at NAVAIR China Lake Propulsion Laboratories (CLPL). Late in 2002, an effort at CLPL began to take shape when ground was broken for the construction of the $30 million Propellants and Explosives Laboratory. MILCON P-453 will consolidate all small-scale—15 pounds or less—explosive and propellant processing operations into a complex of four buildings, totaling

42,097 square feet. The construction will include a 6,512 square-foot administrative building. The 35,585 square feet of laboratory space will house such functions as research, synthesis, formulation and characterization of propellants and explosives. Currently, operations are performed in 35 buildings, many of which were built in the 1940s. The consolidation is expected to result in reduced maintenance costs and improved efficiency. [54]

NAVSEA and NAVAIR Unify Navy Energetics

From a five milligram, low-energy initiator to an 81,000-pound rocket motor, safely harnessing the power of energetic materials is a critical Navy technology. In every Navy weapon this material either burns or blows up. Because Sailors live at sea in close quarters with high-explosive weapons, munitions are an even greater concern to the Navy than for other military branches. The Navy Energetics Leadership Board (NELB) and the Navy Energetics Integrated Product Team (EIPT) are forging a unified Naval Sea Systems Command/Naval Air Systems Command (NAVSEA/NAVAIR) energetics program that represents all four of the Navy's energetics laboratories: Crane, Indiana; Dahlgren, Virginia; Indian Head Divisions of the Naval Surface Warfare Center, Maryland; and NAVAIR WD at China Lake and Point Mugu, California. To educate the Navy's energetics community about the breadth of energetics capabilities and train a new generation of leaders, the NELB has instituted an energetics leadership program. The "Naval Energetics: Collaborating for the Warfighter" program brings together 30 participants from the Navy energetics laboratories.[97]

Survivability/Vulnerability/Lethality

Fighter Engine Project Aims to Cut Damage

Using the Weapons Survivability Laboratory (WSL) at China Lake, Navy and General Electric Aircraft Engines Division are developing a system to reduce the vulnerability to combat damage of jet engines, particularly in single-engine aircraft. The initial testing used the F414-GE-400 engine from the F/A-18E/F. In past conflicts, five more minutes in the air could make the difference between returning home or becoming a POW. The Survivable Engine Control Algorithm Development (SECAD) project is intended to help provide that extra time. Mounting an F414-GE-400 engine on a test stand at China Lake, engineers introduced simulated damage to test the ability of the SECAD controls to detect, identify, and respond to the damage, thus being able to either prolong engine life of provide additional time at maximum thrust. Funded by the Joint Technical Coordinating Group for Aircraft Survivability (JTCG/AS), the tests at China Lake were the first step toward demonstrating the capability of damage detection and response. [98]

Missile Airframe Technology

WD missile airframe technology efforts provide affordable airframe structures, stable weapon flight, increased maneuverability, safe separation from launch platforms, reduced drag, improved aero-prediction and defense penetration techniques, and high-temperature airframes. WD has greatly advanced composite material technology and was instrumental in developing American Society for Testing and Materials standard material test methods that are now used by the industrial community for characterizing the structural performance of filament-wound composite structures. Before this no accepted method to qualify manufacturers existed. WD is developing advanced high-performance motor cases to satisfy insensitive munitions requirements and light-weight high-temperature structures required for high-performance hypersonic-weapons systems. Between 1998 and 2001 composite technology scale-up to a Sidewinder-class airframe was demonstrated and successfully qualified for captive-carriage flight testing. In addition, an all-composite motor case was successfully demonstrated in the Multi-Mission Propulsion Technology Advanced Technology Demonstration (MMPT ATD). This technology is being transitioned to the RAM Risk Reduction and Common Modular Missile Programs. WD is also exploring combined IR-RF radome concepts and lifting-body technology that addresses high-speed, low-drag requirements for high-performance supersonic and hypersonic systems. At the systems level, WD uses the Integrated Hypersonic Aeromechanics Tool (IHAT) for design trade studies and optimization. [99]

Passive Fire Protection

Fire is a leading contributor to attrition of aircraft in combat. However, active fire suppression systems can often be complex, costly, and heavy. Joseph Manchor, of NAVAIR China Lake, co-chairs the Fuel Systems Committee for the Joint Technical Coordinating Group on Aircraft Survivability (JTCG/AS). He discusses various passive fire protection technologies that are low cost and low weight. The Simple Passive Extinguisher (SPEX) involves a reactive agent placed or installed directly within the aircraft compartment. Fire activates the agent, which rapidly fills the compartment and extinguishes the fire. Reactive Powder Panels, upon ballistic impact, will break open and release the encased fire suppressant powder. A JTCG/AS project is investigating for use of an energetic material to enhance powder release from such panels. Manchor further discusses concepts of ionomer fuel containment technology to produce better self-sealing materials; hot surface ignition mitigation to reduce the surface-to-liquid heat transfer when flammable fuels encounter hot components; and intumescent firewalls that respond to fire by swelling several orders of magnitude beyond their original thickness to thermally protect and insulate the structure. [100]

Weapons Survivability Laboratory (WSL)

CL Test Assets Used in Demonstration for Joint Service Team. The WSL at China Lake supported the Joint Services Air Defense Lethality Team (JSADLT) in a one-week training session. JSADLT is a team of reservists from all three services sponsored by the Joint Technical Coordinating Group on

Aircraft Survivability. Their function is to collect data on aircraft combat damage and losses. These data are essential to current and future aircraft as they reveal vulnerabilities in existing aircraft—vulnerabilities that can be fixed—and provide a database of lessons learned for future aircraft designs. LTCOL Anthony Brindisi, the JSADLT lead, said, "China Lake is a superb location for this training because it has the widest selection of aircraft damage replicating combat damage, which provides us with the most realistic training." Live fire testing has paid enormous dividends in the design of more survivable aircraft, as was demonstrated in Operation Desert Storm. During that operation, several F/A-18 and A-10 aircraft returned safely to base after having suffered major structural damage from surface-to-air missiles. [54]

Shoot 'Em Up. We're at the WSL, 10 miles into China Lake's hidden city, 3,800 square miles of high Mojave scrub and mountains. Two hundred yards away stands the helicopter prepped for its final judgment. Though it was built with care and is worth more than $10 million, it is being sacrificed for the future glory of the MH-60s that will go to war. Congress passed the Live Fire Test Law in 1986 that requires survivability testing on all weapon systems, including airplanes, in realistic, full-up, armed configuration. "I can't think of anything more fun than burning things up and exploding things," says survivability test engineer J. Hardy Tyson, standing next to an F/A-18E Super Hornet that looks like it lost a fight with a fire-breathing dragon. Tyson's exuberance notwithstanding, he and his colleagues are scientists and engineers, and every test is exhaustive. "Each test shot," says Jay Kovar, WSL Director, "often takes months to set up and ends in a matter of seconds." "If your testing causes improvements that extend the time you can stay with your aircraft for three to 10 minutes," says Chuck Myers, former Office of the Secretary of Defense Director for Air Warfare, "that's a big thing!" Just how big was proven when U.S. and Afghan forces attacked al Qaeda and Taliban holdouts in one of the biggest battles of the Afghan war. Seven Apache helicopters provided close air support. The Apache had been subject to—and redesigned based on—live fire testing. All seven helicopters were hit. And all seven managed to limp home. [101]

Modeling and Simulation

Joint Standoff Weapon (JSOW)

JSOW Tested at GPS/INS Branch. A JSOW underwent testing in the GPS/INS Branch's Navigation Laboratory. Anticipating the Next-Generation GPS, weapon developers at China Lake are using this specialized facility in the Integrated Battlespace Arena (IBAR) to assess future navigational performance. Both the current GPS signal and a simulated modernized GPS signal are fed to the JSOW simultaneously, and the output of the navigation subsystem is analyzed to determine navigation performance. The GPS modernization test regimen has already been successfully performed on the HARM PNU. [54]

Tomahawk In-Flight Missile Simulator (TIMS) Pod

Saved Program Time and Money with TIMS Pod. "The TIMS Pod has provided an option that allows us to fly a mission profile similar to the Tomahawk cruise missile and simulate the missile's in-flight environment." In conjunction with contractors, engineers are currently developing the Tactical Tomahawk, the next generation of Tomahawk cruise missile. Tactical Tomahawk (TACTOM) incorporates numerous performance and affordability improvements over the current version of Tomahawk. The challenge was how to best go from laboratory testing to an actual missile flight test. The solution was a captive-carry avionics pod that employs TACTOM guidance/new equipment, flown under the wing of an A-3 Skywarrior and an F/A-18 Hornet. The team developed two pods with different testing configurations. [54]

Successful F/A-18 Integration. "The integration of the TIMS Pod on the F/A-18 performed up to or exceeded expectations," said the AWL team member who led the integration of the pod onto the F/A-18 aircraft. "The pod was flown without any hardware or software modifications to the Hornet. The flight tests on the Hornet went very well, and the F/A-18 has proven to be a very capable platform for carrying the TIMS Pod," he added. [54]

Allows Full-Range of Testing. The pods will allow a full range of dynamic testing to be completed before incorporating these upgrades or new systems into the actual missile. The TIMS Pods will reduce risk and result in significant cost savings over the traditional methods the Tomahawk Program has used to introduce updates to the missile. The success of this venture can be attributed to a varied and dedicated group of people from several sites, including Raytheon, Point Mugu, China Lake, and Patuxent River, who have worked well together to make the TIMS Pod a reality. [54]

Virtual Missile Range (VMR)

VMR a Reality at WD. *USS Kinkaid* (DD 965) carried out a Sea Range exercise through the VMR, a remarkable new NAVAIR capability that combines shore-based live and simulated components with a ship's combat systems and onboard simulators to replicate threat missile raids at a fraction of the cost of live firings. A VMR scenario begins with a signal broadcast from a synthetic target generator (STG) located on San Nicolas Island. This signal stimulates the ship's radar and fire-control systems to "see" a threat target approaching. On board *Kinkaid*, a Missile-All-Up-Round Simulator (MARS) unit installed in the NATO SeaSparrow launcher cell performed as an actual missile. The ship calculated prelaunch conditions using the MARS unit and the NATO SeaSparrow system. The signals from the NATO SeaSparrow system were encrypted and transmitted via a wireless data link to the Hardware-in-the-Loop Facility at Point Mugu. There, actual missile hardware mounted on a Carco flight-simulator table "flew" the mission. The

results—a hit or a miss—were instantly relayed back to the ship. Observers in the Sea Range Interoperability Test and Evaluation Center (ITEC) watched the "flights" through the VMR's Real Time Viewer Program. Early in the VMR development, VAdm. Dennis V. McGinn, commander, Third Fleet, stated that "the VMR is an important step toward realizing the full potential that modeling and simulation can provide to the Navy." The VMR has been fully integrated into Sea Range operations, and electronic countermeasures simulations have been installed. Proposals are in place for upgrading the VMR with multi-axis threats, maneuvering threats, vertical launchers and other platforms' missile systems. [54]

VMR: is it Live or Synthesized? Is it a real missile or just a simulation? With the advances made at the Point Mugu VMR, not even expert engineers can tell the difference according to Tom Rozanski, VMR systems engineer. Rozanski was referring to the comments of a Port Hueneme Surface Warfare Engineering Facility engineer who "could not tell the difference" between live missile presentations and the synthetic ones being presented with the VMR Synthetic Target Generator (STG). Not only can the VMR replicate incoming missile threats, now it can use electronic countermeasures (ECM) in attempts to fool the defensive systems. With this latest upgrade, the STG now has the capability of projecting numerous different ECM techniques with any of its incoming synthetic threats. During shake-down tests of the VMR upgrade, numerous presentations were made to the NATO weapon system. All exercises were successfully completed. [54]

Research, Science, and Technology

New Clean-Power Generator

Scientists at China Lake may have found a new way to bring clean power to off-grid targets, radars, repeaters and radios on the test ranges and save the earth's limited supply of fossil fuels. Using an experimental hydrogen fuel-cell concept, engineers are testing a prototype that can turn the sun's energy—collected through solar panels—directly into voltage without messy batteries. Currently the ranges use solar photovoltaic panels to collect and store energy in large banks of batteries, which run the repeaters and other range operations. The prototype $300,000 hydrogen generator at China Lake uses electricity generated by solar panels to electrolyze—or separate—water into hydrogen and oxygen molecules, which enter a fuel cell. The hydrogen gas is stored in a tank and can be used in a fuel cell to produce clean, non-combustive power. The process creates electricity and byproducts such as heat, which could be used during winter months, and water. Energy stored though the process can provide power without sunshine for three to four days. The hydrogen generator provides 950 watts, enough electricity to power two hand-held hair dryers. After another round of testing, the system could be used throughout the base in 500-watt blocks. Actual implementation of the fuel cells on the ranges is about four years away. Eventually the system could have much wider usage throughout the Fleet, and possibly civilian use. [102]

Liquid Bipropellant

Controllable thrust-on-demand propulsion systems are required for numerous military and space applications, including axial propulsion for propelling a payload, propulsive vehicle steerage (known as divert), and propulsive vehicle pointing (known as attitude control). These propulsion systems must be versatile enough to provide the exact amount of thrust required for a specific mission with precision timing. In a number applications, thrust on-demand must be provided in multiple directions to intercept high-speed threat payloads, and propulsion systems must be packaged in a small volume and have minimal weight. WD is developing these propulsion systems for kill-vehicle divert and attitude-control systems (DACS) steerage and attitude control. For this application, WD developed and demonstrated non-toxic hypergolic bipropellants using concentrated hydrogen peroxide (>90% concentration) as an oxidizer and a new class of non-toxic fuels known as Non-Toxic Hypergolic Miscible Fuel (NHMF). Numerous tests indicate that the peroxide/NHMF bipropellant combination has significant promise for DACS application, given its rapid ignition time and decent performance. NAWCWD improved on the original NHMF fuel formulation by developing fuel formulations with the same attributes as NHMF but with enhanced aging characteristics. This is a key attribute required to transition a fuel into fielded weapon systems. In this regard, WD is in the process of patenting several families of fuels that are highly hypergolic with hydrogen peroxide oxidizer and that demonstrate significant robustness in accelerated-aging tests conducted at 150°F. These fuels also show chemical stability in thermal cycle tests between –40°F and 150°F. Additionally, WD scientists conducted an extensive and successful series of 25- and 300-pound thrust tests to demonstrate the viability of the new fuels to provide adequate ignition response times and performance. As a result of these successes, industry is now collaborating with WD under Cooperative Research and Development Agreements (CRADAs) to transition these promising technologies to a number of military and commercial applications. [103]

Micro Electro-Mechanical Systems (MEMS)
Safe-Arm (S-A) Device

A safe-arm (S-A) device is a safety-critical component that prevents accidental detonation by arming a warhead only after the missile has been intentionally launched and flown a safe distance so that the launch platform (aircraft or ship) has time to escape the blast. Traditional S-A devices contain complex assemblies of mechanical parts, are roughly the size of a soda can, and weigh several pounds. State-of-the-art MEMS technology is reducing the size and weight of traditional S-A devices by a factor of 10 or more, thus providing significant increases in missile flight range and available volume for other missile components. Work began at China Lake in 1999 on a

Master Control Unit that simultaneously controls a number of externally located "smart detonators" connected together by an electronic signal cable. Today, each thimble-sized smart detonator contains microscopic explosive components and a MEMS safety mechanism controlled by microcircuitry. Upon command, MEMS aligns the explosive components into firing position. When fired, these tiny components initiate larger explosive components, resulting in warhead detonation. [104]

The Integrated High Payoff Rocket Propulsion Technology Program

Meeting the demand for future Navy missiles requires continuous technology development today. The Integrated High Payoff Rocket Propulsion Technology (IHPRPT) Program, begun in 1994, is an integrated, tri-service/NASA/industry effort to develop and demonstrate innovative, revolutionary technologies that will double rocket propulsion capabilities—boost, space, and tactical—by the year 2010. WD handles 80% of the tactical IHPRPT Program, leading the tactical demonstrator program and bearing overall responsibility for propellants and control systems. Significant progress has been made toward achieving the near-term goals of increased delivered energy and mass fraction, through the development of propellants with higher-energy ingredients (CL-20 and ADN); higher operating pressures, made possible by improved propellants, composite motor cases, and low-eroding nozzles; and innovative thrust-vector-control systems.[105]

Direct Fleet Support

Digital Mapping

Provided Geographic Imagery to the Fleet. WD is creating and distributing to the Fleet geographically organized compilations of digital map data. This effort alleviates a problem with some of the required imagery being on indefinite back-order at Defense Logistics Agency (DLA). Multiple discs were distributed to the Fleet, and Fleet aviators have given very positive reviews. Three hundred sets of the data have been requested. [76]

Digital Precision Strike Suite (DPSS)

Installed a DPSS on *USS Stennis.* Installed a WD developed prototype DPSS system on *USS Stennis* that can rapidly anchor a tactical image to the Digital Point Precision Database to produce a target-quality coordinate that can be used to target precision guided weapons. The DPSS prototype was demonstrated on the *Stennis* during some training exercises. *Stennis* requested installation of the prototype for use during operational deployment to support the war on terrorism. [71]

F-14

NAVAIR's NWTS Point Mugu is currently supporting Commander Fighter Wing Atlantic to TRANSPAC F-14s from Oceana to Atsugi, Japan, in support of OEF. To date, NWTS has assisted Commander Fighter Wing Atlantic with aircrew and maintenance to TRANSPAC three F-14 aircraft. Aircraft arrived at Point Mugu, required O-level maintenance, and were flown to Oceana with Point Mugu aircrew. After maintenance in Oceana, the three F-14s were flown back to Point Mugu for TRANSPAC to Atsugi. [76]

Fleet Weapons Support Team (FWST)

FWST Supported Multiple Operations. The FWST incorporated technical directives for Sidewinder and cluster bomb unit (CBU) fins; introduced JSOW, JDAM, and GBU-24 weapon systems to the Fleet; verified checklists and maintenance manuals for the P-3, S-3, F-14, H-60, and F/A-18 aircraft; introduced support and test equipment for Common Rack and Launcher Test Set (CRALTS), Common Munitions Built-In-Test Reprogramming Equipment (CMBRE) weight test stands, and nitrogen van; provided daily training and technical support to all reserve and active duty Navy and Marine Corps units; and provided technical support and formal instruction to FMS customers from Australia and Spain. [71]

Supported VP-9 and VP-46 Forward Deployment. NAVAIR FWST personnel from Marine Corps Base Hawaii (MCBH) Kaneohe, Hawaii, deployed with VP-9 and VP-46 at the request of Commander Task Force 57 to provide on-site technical and logistical support during OEF. This support consisted of weapons training flights, P-3 weapons system troubleshooting, and logistical support for the squadrons while forward deployed. [76]

Forward Air Controller (FAC) Training

Air Force Training. Twelve Special Operations Air Force FACs, during their training with CAG-14 (at Lemoore) F/A-18 squadrons, came to NAVAIR China Lake to perform pre-deployment training and re-certification of individuals preparing to depart to theatre. The FACs are assigned to Army, Navy, and Allied Special Operations units in-theater when they complete their qualifications and training. Six FACs from one squadron spent three days calling in air strikes from Lemoore F/A-18s equipped with laser-guided training rounds (LGTRs) and Mk 76 practice bombs. Five of the six FACs got their qualifications and were ready to go in-theater. FACs from two other squadrons were able to achieve limited training. [113]

Joint Direct Attack Munition (JDAM)

Support Provided to Fleet F-14Bs and Fallon. NWTS Point Mugu was tasked to provide JDAM capability to Fleet F-14B squadrons. Engineers arrived at Fleet locations and began aircraft modifications and software loading. Personnel then traveled with the squadrons to the NSAWC, Fallon, to assist with planned live drops. Later, Mugu personnel will travel to *USS Theodore Roosevelt* (CVN 71) and conduct similar operations. [76]

Fuzing Training to Fleet. A team from NAVAIR WD traveled to NAS Lemoore for JDAM discussions with the Strike Fighter Weapons School Pacific (SFWSP) and returned Fleet gunners. Another team traveled to NAS Fallon for

discussions with NSAWC, Topgun, and WD. The focus of travel was to identify the current state of training as it might relate to JDAM fuzing reliability. [76]

Joint Fleet Exercises (JTFEX)

Supported *USS Stennis* JTFEX on ECR. The ECR supported a JTFEX involving *USS Stennis*. Two tent cities, representative of the current conflict, were erected on and near Charlie airfield to provide realistic-looking areas of opportunity. A mock-up Scud missile was constructed to add to the overall presentation. Four EW-opposed strikes were flown into this target area from the warning area. [76]

Sea Range Provides Opposition Forces. During Composite Unit Training Exercises (COMPUTEXs) and JTFEXs, the Sea Range provides surface-craft opposition forces for Maritime Interdiction Operations. These operations include visit, board, search, and seizure exercises; small-boat-attacks (SWARMEXs); and small-boat harassment against the battle group. [54]

Surface Targets Team at Port Hueneme Provide Multiple Targets. The WD Surface Targets team at Port Hueneme supplies the improved surface tow target, the aerial target launch ship, the SL-120 support vessel, high-speed maneuvering surface targets, and QST-35 SEPTARs. To add realism to the exercises, personnel onboard certain vessels present challenging scenarios that Navy boarding teams may expect to encounter in actual operations. [54]

Vessels Used for Fast-Rope Boarding and Sniper Exercises. Used Link 11 Connectivity. WD vessels have also been used for helicopter fast-rope boardings and live-fire sniper exercises. In COMPUTEX and JTFEX events, WD also uses Link 11 connectivity with the sea-borne combatants to inject intelligence and target information for use in the overall battle scenario. [54]

The Sea Range Also Supports Missile Exercises. Fleet ships launch NATO SeaSparrow missiles and Standard Missiles I and II against BQM-34, BQM-74, Vandal, and MA-31 aerial targets. Carrier Air Wing air-to-air and air-to-surface missile firings are conducted on the Sea and Land Ranges. At the Sea Range, WD supplies BQM-74 aerial targets for air-to-air exercises and QST-35 SEPTARs and towed barges for surface attack exercises. [54]

Third Fleet Recognition of Support for JTFEX 02-2. Following is an excerpt of a COMTHIRDFLT message. "I want to thank WD for the superb support you provided to the *Abraham Lincoln* battle group during Joint Task Force Exercise 02-2. Our goal in the planning of a JTFEX is to provide the most realistic training possible in preparing a battle group for forward-deployed operations. This goal was greatly facilitated by the quality of range service, targets and opposition force provided by WD. The conditions for achieving success in this large and complex exercise were created by your dedicated planning efforts and the quality of services provided. You have my sincere appreciation. You have played a vital role in preparing the Sailors and Airmen in the *Abraham Lincoln* battle group for the challenging tasks they will encounter during their forward deployed operations." [87]

Joint Standoff Weapon (JSOW)

JSOW and JDAM projects have provided two CMBRE sets each to seven Navy carriers and two each to three Marine Corps Air Stations. [54]

Training Provided to Pacific and Atlantic Fleets. Smart training for a smart weapon was the goal of the JSOW Project Office when they invited Mobile Ordnance Training Team (MOTT) members from the Pacific and Atlantic Fleets for a visit. At the NAVAIR WD China Lake site, MOTT members got a crash course in how to use a maintenance package called the CMBRE. Staff at the Point Mugu site demonstrated its use and offered the opportunity for some hands-on training with the CMBRE package and a JSOW, to simulate how it would work in the Fleet. [54]

Common Munitions Built-In-Test Reprogramming Equipment (CMBRE) Package is Ruggedized for Ship-board Use. The CMBRE equipment is completely ruggedized for shipboard use, and will initiate the munition's built-in-test (BIT) component of the JSOW. It will also upload the OFP or missing planning and GPS data. What makes the CMBRE different is the decision made in the beginning by the project office to get the Fleet trainers involved. In about three hours, the five MOTT trainers were confident they could go to the next carrier to deploy with JSOW aboard and train the ordnance handlers in the use of the CMBRE with JSOW. [54]

Maintenance

Portable Radar Test Set Supports Operation Enduring Freedom. The NAVAIR F/A-18 AWL at China Lake worked with *USS John C. Stennis* avionics repair shops to troubleshoot aircraft radar systems for F/A-18 Squadrons during their deployment to the Arabian Sea in support of OEF. AWL personnel developed a portable radar test set, installed in a ruggedized suitcase, to test radar systems in their natural environment, while installed in the jet. Responding to a request from the Commander of the Air Group just ten days before their deployment, a team of three AWL engineers accompanied the Radar Calibration Collection Module (RCCM) out to the ship, then operating off the coast of San Diego in the final days of pre-deployment work-ups. The team provided hands-on training to all three Hornet squadrons in CVW-9, VFA-146, VFA-147, and VMFA-314. [87]

Meteorology and Oceanography (METOC)

Developed a METOC Guide for Strike Warfare. The Naval Pacific METOC Detachment at Point Mugu prepared a "METOC Guide for Strike Warfare." This project is designed to provide operational METOC personnel with a quick-and-dirty guide on the systems, platforms, and weapons that support Strike Warfare. In addition, METOC will be playing a

role in the weapons of mass destruction (WMD) strike scenarios scripted into a carrier JTFEX exercise. The effort will involve scenario development and execution, chemical/biological fallout dispersion modeling, and training and back-up for COMTHIRDFLT and METOC personnel. [76]

Missile Assist Team (MAT)

Supported Multiple Operations. During FYs 2000 and 2001, WD supported 80+ land-based MAT operations, 16 at-sea missile operations, 20 Integrated Weapon Systems Reviews (IWSRs), 16 Combined Air Exercises (CAXs), four Weapons Tactics Instruction (WTI) courses, 30 land-based Bomb Assist Team (BAT) exercises, 10 at-sea BAT exercises, and seven Aviation Ordnance Readiness Reviews (AORRs). This direct warfighter assistance/support also included forward-deployed assistance requested in Kosovo and OEF efforts. [71]

Missile Presentencing Inspection (MPI)

Responsible for the Inventory, Inspection, and Re-Certification of Air-Launched Missiles Aboard Returning Aircraft Carriers. Under the direction of the MPI Program, WD was responsible for the inventory, inspection, and re-certification of air-launched missiles aboard returning aircraft carriers including aircraft interface, operation, maintenance, modifications, and training to Navy and Marine Corps aviation units. [71]

Missile Sentencing Inspection (MSI)

Sent MSI Team to Guam. At the request of the commanding officer, NAMU-1 (Guam), WD sent a MSI team to Guam to perform MSI on all air-launched missiles in support of OEF. [76]

Training

Conducted HARM University (HARM-U) for the Fleet. The ARM Program Office completed its third HARM-U of the year, the twelfth since its inception. This four-day weapons training course teaches the intricacies of the AGM-88 HARM weapon system to subject-matter experts from the Fleet. While HARM is a fire-and-forget weapon, a high level of user knowledge, mission planning, and training are required to use the missile to its greatest capability. The AGM-88 HARM is an air-to-surface tactical missile designed to seek out and destroy enemy radar-equipped air defense systems. It is currently flown on the F/A-18 Hornet, EA-6B Prowler, and F-16 Viper. This course exposes Fleet aviators to graduate level instruction on the operation of HARM, enabling them to return to their squadrons and air wings to teach other aviators. Classes of 20 to 30 students comprise Navy, Marine Corps, and Air Force aviators. These classes sometimes include civilian scientists and engineers from all of NAVAIR, WD, and other agencies involved in the HARM program. Another WD product for HARM users is the HARM Part Task Trainer (PTT). The PTT is an F/A-18 Hornet cockpit emulator that can be used by aircrew for HARM familiarization, training, and mission rehearsal. The program emulates an F/A-18 HARM interface, including cockpit switchology and displays. [54]

Third Fleet Focuses on Protecting, Training. Third Fleet Makes Extensive Use of NAVAIR's Western Ranges for Training. Full-Time Liaison Appointed Aboard the Flagship, *USS Coronado*. The Third Fleet is a formidable force of more than 80 ships, 1,200 aircraft, and 200,000 Sailors and Marines. What sets the Third Fleet apart from the rest of the Navy is its intense focus on pre-deployment training, as well as its central role in evaluating state-of-the-art technology for naval and joint operations. WD actively supports the Third Fleet in these efforts. The Third Fleet is responsible for the eastern and northern Pacific Ocean, an area of 50 million square miles. Because the training process makes extensive use of NAVAIR's western ranges, a full-time WD liaison representative serves aboard the Third Fleet's current flagship, *USS Coronado* (AGF 11). The liaison provides on-site advice and coordination to the Fleet during planning for training events on the NAVAIR ranges (primarily Sea Range). Because of the complexity of these events, involving multiple ships, aircraft, targets, surveillance instrumentation, and range clearance, the on-site support is invaluable. [106]

Provided Training and Readiness to Third Fleet. VADM Bucchi Quote. From COMTHIRDFLT: "I wish to convey my sincere appreciation for the top-notch support your commands provided during a demanding year of training for Third Fleet deployers. Your outstanding efforts in 2001 helped us maintain our fighting ships and squadrons at the highest possible readiness, maximizing efficiency whenever possible through innovative exercise scheduling and consolidation. Most notably, it was the excellent people of your organizations who, through their dedicated planning and execution of all training evolutions, upheld the superb legacy of professionalism and Fleet support that your organizations deserve. Please pass my sincere thanks and congratulations on a job well done to each member of your range support team. Bravo zulu!" [95]

Bombing Conducted on the Land Range. At the Land Range, Fleet air units see bombing action at the Coso Military Target Range and the Superior Valley Tactical Target Range. The aviators also hone their skills against threat emitters on the ECR. Aircrews and airborne sensor operators learn to locate and identify enemy mobile weapons systems at San Nicolas Island, Point Mugu, and the Land Range. In these time-critical-strike operations, highly realistic target shapes are moved to various locations, often camouflaged, by WD personnel. Finally, the restricted airspaces above the Land and Sea Ranges are used by the Fleet for no-fly-zone exercises. NAVAIR WD has supported the Third Fleet for nearly 30 years. [54]

Sea Range Trials

Conducted Demanding Sea Range Trials for *USS Mobile Bay* (CG-53). Combat System Ship Qualification Trials (CSSQT): the name says exactly what this exercise is all about. Start with a Navy ship—in this case the Aegis cruiser *USS Mobile Bay* (CG-53)—fitted with the latest in combat

systems: guns, missiles, radars, and a host of other weapon and weapon-related equipment. Then qualify those systems and the men and women who operate them to the most rigorous standards of proficiency. And call the exercise "trials" because the job is tough, relentless, and designed to bring out the truth about the ship's readiness to go to war. *Mobile Bay* came to the CSSQT on NAVAIR's Sea Range fresh from a $10 million overhaul in San Diego. [54]

Formidable Ship Armament. *USS Mobile Bay's* armament includes vertical-launch systems for Tomahawk**,** Standard Missile, and antisubmarine rockets; Mk 46 torpedoes; Harpoon launchers; two 5-inch/54 guns; and, for the really up-close threats, a super rapid-blooming off-board chaff system and a pair of Phalanx close-in weapon systems. At the heart of *Mobile Bay's* offensive and defensive capabilities is the Aegis system, built around an advanced, automatic detect and track, multifunction phased-array radar called the AN/SPY-1. This high-powered radar handles search, track, and missile-guidance functions, all simultaneously, with a tracking capacity of more than 100 targets. [54]

Conducted Multiple Manned Aircraft Raids. WD personnel at Point Mugu raised the stress level considerably when they conducted multiple manned aircraft raids against *Mobile Bay*, with each of the aircraft realistically simulating an incoming threat. WD flew multiple-tracking missions with Q-Lear and NKC-135 Electronic Attack aircraft. Two BQM-74E aerial targets flew five littoral tracking presentations over and near San Nicolas Island to exercise the Aegis combat system's capability to detect, track, and engage anti-air warfare threats in a littoral, high-background-clutter environment. [54]

Launched Live Standard Missiles. Five target scenarios were presented by Sea Range personnel using two BQM-74Es, one BQM-34S, one AQM-37C, and one Vandal Extended-Extended Range (EER). "Full speed ahead," is *Mobile Bay's* motto. It speaks not only to her speed—she's capable of more than 30 knots—but also to the way she does business. During Desert Shield and Desert Storm operations, the ship became the first Battle Force Anti-Air Warfare Commander to control a four-carrier Task Force. *Mobile Bay* launched 22 Tomahawk missile strikes and controlled carrier-launched attack aircraft that contributed to the complete destruction of the Iraqi Navy. [54]

Crew Systems

High-Altitude Parachute Life-Support System (HAPLSS)

British Successful In Tests Of High-Altitude Parachute. Test Jumpers Fly 40+ Miles To Landing Site. Detachment Commander Squadron Leader Roger Harrison and his 55 colleagues were at the National Parachute Test Range (NPTR), China Lake, to test a new parachute system. The HAPLSS combines a parachute with high-altitude survival gear. HAPLSS is designed for use in high-altitude, high-opening (HAHO) operations to transport select British military teams into hostile territory. HAHO allows the jump aircraft to deliver its cargo from a significant standoff range, thereby reducing the odds of enemy detection and increasing survivability. Ninety-eight tests were executed at China Lake. Six used anthropomorphic dummies; the others were live jumps at altitudes that increased incrementally, beginning at 12,000 feet above mean sea level (MSL). About 50 of the jumps were done above 25,000 feet. The parachutists jumped five at a time. Team members were elated as altitude records were broken at each increment. At altitudes above 25,000 feet, the parachutists were breathing pure oxygen before jumping, to counteract the effects of decompression sickness. Flight Lieutenant Chris Heathershaw typifies the enthusiastic appreciation of the British team: "Range Control is fabulous. At other bases we always had lots of downtime because of support coordination problems, but here it all ran very smoothly." [54]

Homeland Defense

Established a Counter-Terrorism/Homeland-Defense Response Team Network

The network responds to DOD/warfighter requirements and formal data calls, providing technologies and ideas to support the counter-terrorism and homeland-defense efforts. Twelve proposals, developed jointly by the NAVAIR (WD and AD), have been submitted to the ONR science and technology (S&T) Data Call. These mature technologies can transition to operational systems within 30 days to one year. [76]

Established Command Center

When America was attacked 11 September 2001, part of WD's immediate response was to recruit a team to set up a Command Center from which its leadership could operate. This center had to support the warfighter, and it had to be up and running quickly. "In an unprecedented time frame of only three weeks, walls were removed, classified and unclassified networks and systems were set up, video teleconferencing and other communications systems were installed and operational," said CDR Christy Hartigan, WD executive assistant. Within five weeks, an "open storage secret" environment was created, giving WD personnel at China Lake accessibility 24 hours a day, seven days a week. The Command Center continues to perform three distinct functions: (1) force protection, providing a secure, state-of-the-art weekly meeting place for that team; (2) emergency operations, functioning as a central hub for the Naval Air Weapons Station commanding officer in the event of a mishap or natural disaster; and (3) warfighter response, maintaining constant connection between warfighters and engineers. [54]

Explosive Ordnance Unit (EOD): Trained for the Challenge

The EOD at China Lake provides emergency services to the flight line for ordnance on aircraft, in the event of a mishap or accident and for bomb threats. The detachment is also involved in force protection training and has served as co-host for the FBI Academy. The New York Fire Department bomb squad trained with EOD as well as the California Highway Patrol. EOD operates the only thermal treatment facility for explosive hazardous waste permitted on the West Coast. "We treat 70,000 to 200,000 pounds net explosive weight per year," said CWO2 Charlie Payne, assistant officer in charge of the unit. For a change of pace, members of the detachment go diving—in the Mojave Desert as well as in the ocean. EOD personnel dived into Lake Isabella to look for blockage on the outfall of the dam and were also asked to help recover a sunken boat. Joint exercises with foreign detachments are part of the training process. For example, the U.S. has adopted the Australian techniques for bottom-line searching. At Airport Lake, a dry lake bed, EOD watched a British Royal Air Force EOD search for and destroy duds. U.S. EOD detachments have trained with their counterparts from Korea, Thailand, Australia, Japan, the United Kingdom (U.K.), Spain, Germany, France, Italy, Norway, Israel and Croatia. [54]

NAVAIR/FBI Explosives Classes Conducted

The FBI Large Vehicle Bomb Post-Blast Crime Scene School was held at China Lake. Law enforcement personnel from nine federal, state, and local agencies and military EOD personnel received instruction in improvised explosives and incendiaries, blast injury and response, a case study of the Oklahoma City incident, and the processing of bombing crime scenes, as well as a field exercise in post-blast evidence recovery and device reconstruction. The EOD detachment provided support in construction and detonation of a 500-pound improvised "vehicle bomb" and arranged for classroom and practical training areas. [76]

NAVAIR's Warfighter Response Center (WRC) Links Warfighters to Engineers

As part of NAVAIR's response network, the WRC helps with any questions or data calls on OEF and Noble Eagle. It also provides secure communications. The concept of design is based on a team effort with the WRC linked to the Force Protection Condition command and control and the Emergency Operation Center. Fleet help desks and call centers are at NAVAIR's national level of attention and are directly linked to the Navy's Integrated Call Center located in Norfolk, Virginia. The WRC has already resolved many difficult issues for warfighters from the Navy, Marine Corps, Army and the Air Force. [54]

WD Outfitted West Coast Combat Air Patrol F/A-18Es with Eight Advanced Medium-Range Air-to-Air Missiles (AMRAAMs)

This will allow VFA-115 to effectively perform West Coast Combat Air Patrol. [76]

Seminars Focus on Anti-Terrorism

The Navy's Center for Asymmetric Warfare (CAW) and the Ventura County Terrorism Working Group sponsored the first of an ongoing series of anti-terrorism training events. The seminar was attended by more than 200 law enforcement personnel. The CAW is a national center of expertise designed to recognize, counter, and control the effects of asymmetric warfare. These include terrorism, weapons of mass destruction and information warfare. The CAW's purpose is to bridge the gap between the DOD and federal, state, and local responders. The training was primarily intended for first responders and supervisors from fire, law enforcement, emergency medical services, public health, and other agency representatives. [54]

Teaming with the Coast Guard for Homeland Defense

NAVAIR WD, Naval Base Ventura County, and the Coast Guard are exploring a plan to house UAVs at Point Mugu. That location would have operational advantages for the Coast Guard as it executes its Deep Water Program, a multi-year, multi-phase effort to replace all its vessels, aircraft, and technology. Not only would the partnership with Point Mugu provide a maritime test environment for the new UAVs, it would also provide expertise; NAVAIR has the engineering capabilities to outfit the UAVs with the specialized sensors and instrumentation required for the Coast Guard mission. The UAVs, housed in an existing hangar on the flight line, would have immediate access to the operational and test areas, all within secure, restricted airspace. [3]

Special Weapons and Projects

Advanced Oxidation Technologies (AOT)

Advanced Oxidation Technologies: The Future for Wastewater Treatment? AOTs refer to a group of chemical and physical processes that may be used for air or water treatment and purification. These techniques are all sources of the hydroxyl radical, a very powerful oxidizing agent. In many cases, the target contaminants can be completely oxidized, producing only carbon dioxide and water. A photocatalytic oxidation system was tested at Naval Air Depot Jacksonville to evaluate the potential for treating high-strength organic wastewater. The photolytic process uses a combination of ultraviolet light, hydrogen peroxide, and a particulate semiconductor photocatalyst. A variety of tests were performed, and impressive results were obtained. Current laboratory work being performed at China Lake, California, is focusing on improved semiconductor catalysts applications. Semiconductor materials have been synthesized, characterized, and tested, and are being validated against industry standard materials. Testing is also being done to

determine the applicability of the photocatalytic process for the treatment of other types of contaminated wastewater. It is envisioned that improvements in photocatalysts, when coupled with technologically advanced reactor systems, will reduce water-processing costs significantly, while greatly minimizing waste production and disposal. [107]

Fuel Cells

Fuel Cells on the Way in California. The Department of the Navy is plugging in a $1.5 million fuel cell program in California. Nine fuel cell systems are being delivered under contract to the Navy Renewable Energy Division at China Lake. The nine systems will be installed at three naval activities. Eight will provide electricity and hot water in the bachelor-enlisted quarters, a gymnasium, and laundry facilities at Naval Air Station North Island and the Submarine Base in San Diego. One system will provide electricity and heat to an indoor pool at China Lake. Installation of the fuel cell systems is under way, and the system will operate for one year under this program. "The purchase of these systems represents the first major investment by the U.S. Navy in this technology and will showcase installations that can be duplicated on most military facilities," said the manager for Renewable Energy Programs, China Lake. [108]

Warfare Analysis

Joint Strike Fighter (JSF) Team Recognized for Efforts. Fifteen WD employees were recognized for their dedicated efforts in the JSF Engineering and Manufacturing Development (EMD) source selection. The EMD contract award to Lockheed Martin is the largest acquisition program in DOD history. "The JSF program leadership from Washington, D.C. came here and presented awards to the people who participated in the source selection," said Scott Smith, JSF WD site director. "We evaluated the Lockheed and Boeing designs and selected Lockheed as the winner. Our people were part of a larger team of multi-service, multi-disciplined people." WD is supporting JSF in many different functional areas and disciplines, including mission systems software and avionics, interoperability, computer architecture, survivability, live fire testing, electronic warfare, weapons integration, mission planning, and system test and verification. [54]

More Than 60 Projects Completed on Warfare Analysis. One major project was the JDAM Product Improvement Program Analysis of Alternatives. Options for increasing warfighting effectiveness were defined and evaluated and results initiated the Precision JDAM program. Another effort initiated the Advanced Antiradiation Guided Missile (AARGM) program by assessing the warfighting contribution of a set of antiradiation weapon options, and a project began in 2001 to evaluate the potential benefits of a naval unmanned combat air vehicle (UCAV) to battle group operations. In 2000 and 2001, the Strategic Analysis Group (SAG) provided quick-look analyses of Operation Allied Force and provided analytical support for the 2001 Quadrennial Defense Review (QDR). The SAG also conducted studies on how network-centric warfare could have improved strike performance in Allied Force, on the warfighting value that UCAVs could bring to OEF, on options for integrating precision JDAM on the F/A-18 aircraft, and on the utility of air-launched decoys. [110]

General

Management

Naval Air Warfare Center Weapons Division. "At WD we pride ourselves on being at the leading edge of technology and innovation, ensuring the aircraft weapon systems we buy work effectively. Aviators at the point of the spear in Naval Aviation depend on us for that, and we won't let them down."—*CAPT Mark J. Swaney, vice commander, NAWCWD.*

"Our workload covers the full spectrum from weapons development to systems integration, test, and evaluation. Sixty-five percent of our operations are dedicated to T&E, while 35% are for training. We're also involved in the early stages of data fusion relative to Network Centric Warfare. With respect to training, we support Fleet Battle Experiments by providing the overall environment and by injecting real and simulated threats into practice operations."—*Paul Knight, NAWCWD deputy for programs, Pacific Ranges and Facilities Department*.

"We're responsible for testing and evaluating the integration of weapons systems in aircraft. The dynamic world of warfighting technology demands flight testing, and we're determined to do our part in making sure those at the point of the Navy spear have the most effective and reliable aircraft and weapon systems to do the job."—*CAPT Mike Rabens, commander, Naval Test Wing Pacific, Point Mugu*. [111]

Demonstration Project. Most of the 5,000 employees who work at China Lake and Point Mugu work under a special personnel system, Demonstration Project that could serve as a model for civil service reform across government. Essentially, the system aims to give managers increased flexibility to move employees around, reward excellent workers, and punish bad performers. The China Lake system uses broad pay bands and a pay-for-performance system, and emphasizes tenure less than the standard federal personnel system does. It also features less rigid job descriptions than are usually found in government and other characteristics that reformers envision adopting across government. The ability to tie an employee's salary to the employee's performance is something that many federal managers complain they don't have, because increases under standard federal personnel rules follow strict rules that emphasize tenure. [112]

Weapon Platform Integration

F-14

F-14 Tomcat/Bombcat Team Commercial Off-The-Shelf (COTS) Applications and Integration. The Tomcat/ Bombcat team partnered with Microsoft on some of the COTS applications and integration. In fact, Microsoft's President, Steve Ballmer, highlighted the success of F-14s in-house Earned Value Management System (EVMS) efforts at the Federal Office Systems Exposition (FOSE) convention when he said: "We've been working with the F-14 Program Office at NAVAIR on a set of integrated management tools to maintain, track, and help deploy that particular Fleet. The project saved the Navy about $270 million and won them one of the Hammer Awards for hammering out the bureaucracy involved in some of these processes." [113]

F/A-18

F/A-18 Advanced Weapons Laboratory (AWL) Reaches SEI Level 4. The F/A-18 AWL's Software Development Task Team successfully reached the SEI's Level 4. This prestigious ranking puts the AWL in the top 9% of the world's software developers. [114]

Testing and Evaluation/Range Support

Navy Combat Archer (NCA) Team

NCA Team Supports Marine Exercise. 150 Missiles Launched. The WD NCA team played a crucial role in a Fleet air-to-air missile exercise held at the Southern California Offshore Range (SCORE). Marine F/A-18 units from VMFA-314 and Marine Air Group 11 (MAG-11) launched a combination of 13 AIM-9M, AIM-7M, and AIM-120A missiles against BQM-74 and Tactical Air Launched Decoy (TALD) targets during this exercise. The NCA team provided missile telemetry encryption and verification support at NAS Miramar, California, as well as real-time missile performance analysis on-site on San Clemente Island. Data from the launches were logged into the NCA performance database, and reports of missile performance were forwarded to the launching squadrons. The NCA team supported more than 150 missile launches. [113]

Rapid Airborne Mine Clearance System (RAMICS)

Tested at Unique Water Tank Facility. A 50-foot-diameter, 32-foot-high steel tank filled with 450,000 gallons of water was built into the side of a remote hill at China Lake. Mounted on a platform some 500 feet further up the hill was an AH-1F Cobra gunship with its M197 20-mm gatling gun pointing toward the surface of the water. Several feet below the water surface, a simulated enemy mine was moored. The tank and platform constituted a new test facility built for the RAMICS Advanced Technology Demonstration. The demonstration showed that shallow-water naval mines could be neutralized with a specially designed projectile fired from a helicopter-mounted, laser-targeted, 20-mm Gatling gun. This effort was sponsored by ONR and directed from Naval Surface Warfare Center Dahlgren Division's Coastal Systems Station (CSS). Several Raytheon, Inc., offices were involved in the project. [113]

Electronic Warfare

CY00 Electronic Warfare (EW) Software Suite

Comprehensive Improvement. WD completed development and all developmental testing of the CY00 EW software suite, the most complex and comprehensive improvement yet to the Fleet's airborne EW systems. CY00 deployed the first-ever significant update to the ALQ-165 jammer UDF and a new ALR-67E(V)2 RWR UDF, adding for the first time significant situational awareness capability against fourth-generation surface and airborne radar threats. The entire CY00 EW suite performed smoothly in developmental test. The CY00 software suite installs on the F/A-18C/D, F-14B/D, and AV-8B aircraft. [92]

Integrated Defensive Electronic Countermeasures (IDECM)

Interoperability Achievement. IDECM is a tri-service, multiplatform program that integrates advanced EW technologies with multiple aircraft sensor systems. IDECM is designed to detect and respond against IR and RF threats. The integration of IDECM with the platforms involves a level of sensor fusion and interoperability never before achieved on Navy aircraft. [115]

Modeling and Simulation

Integrated Battlespace Arena (IBAR)

This world-class facility at China Lake comprises nine laboratories and facilities. Tests range from the subcomponent to theater levels with a degree of fidelity, flexibility, and dependability unparalleled in the DOD. Facilities are linked nationwide with fiber-optics, ethernet, and microwave telecommunication capabilities. It houses the Navy's first cockpit simulation of its kind—the Virtual Prototyping Facility (VPF). The VPF has the Navy's first cockpit simulation to include communications to and from the simulated aircraft and the weapons. Collectively IBAR scientists have more than 72 patents to their credit and are frequent contributors of papers and journal articles that explore cutting-edge issues and techniques in modeling and simulation. [116]

Research Science and Technology

Laser and Optical

Laser and Optical Technology. Other China Lake developments include the interferometric surface scanner, bowl-feed polishing, ultra-high-vacuum deposition, and a portable CO_2 laser. [117]

Joint Helmet Mounted Cueing System (JHMCS)

First Launch Using Helmet. An AIM-9X shot from an F/A-18 on China Lake's Land Range was the first launch using the JHMCS and included deployment of IR countermeasures from the QF-4 target in a one circle, look-down engagement. The launch parameters were close to the maximum off-boresight angle for the new missile. The missile tracked through the countermeasures and had a solid track on the target hardbody through the closest point of approach. In addition to this test, 14 AIM-9X captive missions—including VX-9 DT/OT missions—were conducted. [113]

Direct Fleet Support

Rim of the Pacific (RIMPAC)

"Pacific Blitz" Theater Missile Defense (TMD) Exercise in Hawaii. The AQM-37 IPT supported RIMPAC 2000 and Pacific Blitz 2000 exercises at the Pacific Missile Range Facility, Barking Sands, Hawaii. Two AQM-37s were successfully launched and flew 80,000-foot Mach 3.0 profiles. The following day, one AQM-37 in a TBM profile lost roll stability at launch. This was the first launch from an F-16 at Mach 1.8. A second TBM-configured target was launched at Mach 1.6 later in the day and flew successfully, as did another 80,000-foot, Mach-3.0 profile. Five AQM-37 targets were launched. Other target support for this effort was staged from Hickam AFB with ALQ-167 EA pods. AST-6 threat emitter simulators were flown on Q-Lear and F/A-18 aircraft against the various ship and air wing combatants. [113]

Weapons and Weapon Systems

Air Deliverable Depth Bomb (ADDB)

Up until now, Naval aircraft did not have a simple, reliable method of attacking submarines in shallow littoral waters. WD, working with industry, developed a Hydrostatic Firing Device (HSFD). This device uses a hydrostatic sensor that takes the place of the Mk 75 destructor used in the Quick Strike mine, resulting in the ADDB. The new device accurately initiates at a predetermined depth. This system consists of a 500-pound Mk 82 general purpose bomb with a Mk 32 arming device in the nose fuze well, the HSFD in the aft fuze well, and either a Mk 15 or a BSU-86 high drag tail fin. The HSFD has four manual depth settings and the ability to change to a default setting in flight. This system is currently being qualified for the P-3 aircraft, but can support F/A-18s with the Fuze Function Control Set (FFCS) communication system. The HSFD was developed through a Cooperative Research and Development Agreement (CRADA) with Raymond Engineering Operations (REO). China Lake conducted the design work, and REO packaged the design into four validation test units. This new capability uses existing Fleet assets, lowers logistics costs, and makes use of a very inexpensive HSFD. WD is also trying to get funding to develop an all in one hydrostatic fuze. Development began in 1999, and a production decision is expected in early 2004. [118]

Bomblets

A WD test manager received an urgent request from the U.K. Working through the Navy International Program Office, she set wheels in motion, and soon a shipment of CBU-87 combined-effects munitions containing BLU-97 bomblets was en route to WD from Britain. Setting up for the tests required extensive redesign of tracking camera layouts, ground video installation, new target surveys, and explosive ordnance clearances. Tests began within one week of the initial phone call, and British Harriers, Tornadoes, and Jaguars were soon participating in safe-separation, accuracy, and hazard-footprint testing. [119]

High-Speed Antiradiation Missile (HARM)

HARM. The team provided direct support to squadrons discussing specific targeting information. HARM also responded frequently to specific emitter questions from the Fleet and Air Force. The Pacific Test Wing and HARM team supported Kosovo operations by generating a new theater ELINT file to allow HARM to prosecute new threats. The team provided direct support to squadrons discussing specific targeting information. HARM responded frequently to specific emitter questions from the Fleet and Air Force. [120]

More Than 1,000 HARMs Fired. USN, Air Force, and allied aircraft fired more than 1,000 HARMs during the air campaign in Kosovo. A HARM Tiger Team from WD deployed to Italy to support forward-deployed forces. The team tested more than 400 missiles in 36 days. Team members at China Lake developed tactical solutions to defeat particularly complex enemy air defenses. Solutions were provided to Fleet HARM users in near real-time and resulted in confirmed hits. Notably, no aircraft were lost to enemy air defenses while HARMs were in flight. (circa 1999) [121]

Harpoon/Maverick

VP-Squadron Missile Support. Harpoon/Maverick System. The VP-Squadron assisted in (1) troubleshooting Harpoon and Maverick missile systems on various aircraft, (2) obtaining an AWW-13 POD for SLAM that was put on a VP-16 aircraft in Jacksonville, (3) getting two Real Time Mission Planning Systems (RTMPS) for programming the SLAM missile, and provided information to PMA-290 on an AWW-13 POD that failed during missile launch. [120]

Joint Direct Attack Munition (JDAM)

JDAM Support. The JDAM program office completed JDAM software suite improvements to meet a potential early Fleet capability. In addition, the JDAM Kosovo Support Team composed of WD logistics personnel from China Lake, NAS Lemoore, and the JDAM System Program Office (SPO) at Eglin AFB completed a successful mission in support of Joint Forces Operations in Hungary. The mission provided JDAM capability to the Marine F/A-18s of MAG-31. The team provided an updated JDAM software suite for programming the weapons, refresher training, delivery of the latest Technical Manual, and assembly and loading checklists, as well as the JDAM tailkits and fuzes. And a late-breaking task was completed to travel to Beaufort, South Carolina, to train

VMFA (AW)-332 on JDAM. Also completed was a JDAM Contingency Training Plan, in coordination with the JDAM Program Office, for rapid response training of Navy/Marine Corps squadrons in JDAM build-up/loading/employment. (1999) [120]

F/A-18 Operational Flight Program (OFP) Successful. WD accelerated development of OFP 13C+ by four months to bring F/A-18/JDAM capability to the Fleet. (1999) [120]

First Tactical Deployment. JDAM saw its first tactical deployment and proved all-weather and precision guidance. The F/A-18 IPT responded to a request from PMA-265 and the JDAM IPT to make changes to F/A-18 software in support of Marine squadrons deploying to the Kosovo area. (1999) [122]

Targeting Systems

ALE-50 Towed Decoy, Highly Effective. The ALE-50, a towed RF decoy designed for the F/A-18E/F, F-16, and B-1B aircraft, was deployed to the Kosovo theater with the Air Force. In response to anticipated threats in the Kosovo region, WD's Survivability Division tested the effectiveness of the decoy against threats on the Land Range. *Aviation Week & Space Technology* (May 31, 1999), citing Air Force officials, reported that 30 SAMs had been fired at B-1 bombers over Yugoslavia. Of these, 10 actually locked on to the B-1s and then were diverted to the decoy. [122]

Reconnaissance Systems

Advanced Tactical Airborne Reconnaissance System (ATARS). ATARS provides near-real-time high-resolution digital imagery in day, night, or under-the-weather conditions. In 1994 the Marine Corps assumed management of ATARS as lead service. In Kosovo, WD supplied our Marine Corps with the ATARS. Flight operations were conducted in support of NATO objectives, attacking military targets throughout the former Yugoslavia. The squadron's commanding officer described ATARS as "indispensable to our Marines." [121]

ATARS. Capability Demonstrated. On March 16, 2000 ATARS demonstrated the capability to provide imagery of a target more than 170 miles distant in less than 55 minutes from receipt of tasking. The tasking came by means of a radio call from an imagery analyst. The ATARS flight crew was waiting in a "5-minute alert" posture when the tasking was received. The crew flew the aircraft 170 miles to the target and gathered radar, electro-optical, and IR imagery. The flight lasted a mere 36 minutes. The two digital tapes were immediately removed and processed. The Marine imagery analyst had his requested imagery in less than one hour from initial request. The ATARS is a significant advance for Marine Aviation. This system returns to the Marine Corps an essential, survivable, reconnaissance asset that has been absent since the retirement of the RF-4B Phantom in 1990. (1999) [120]

ATARS. Early Operational Deployment. The WD F/A-18 AWL supported a MAG-31 request to install ATARS on a WD DT asset F/A-18 and transfer it to the Operation Allied Force theater. Three F/A-18 AWL military and seven civilians reported to the theater of operations to support deployment. WD was requested to have aircraft and support assets on the ramp at Beaufort not later than May 8 and have all personnel in theater not later than 72 hours after the arrival of MAG-31 combat forces. [120]

ATARS/FA-18. WD installed ATARS and provided training. In May, the F/A-18 AWL was requested by MAG-31 to install the ATARS on a WD F/A-18 and transfer the aircraft to Operation Allied Force. WD was also asked to supply additional ATARS equipment, instructors, and a training syllabus to train MAG-31 crews in the Kosovo theater. With strong support from Boeing and Lockheed Martin, a 10-person military and civilian team from the AWL was in-theater to support the ATARS deployment within 72 hours of the arrival of the MAG-31 combat forces. Marines strongly praised the system's combat success. [122]

VFMA(AW)-332 Praises Performance of ATARS in Kosovo. Excerpt from a message from the commanding officer of VFMA(AW)-332: "On the combat success of ATARS, in a word – indispensable. We currently have two systems installed. Two aircraft were airborne almost continuously. We have well over 100 hours on the two systems without a single failure of ATARS. With the exception of JSOW and JDAM, which were just delivered, every type of air-to-ground ordnance has been dropped or fired off the ATARS aircraft. The aircraft have been SAM tested and the RWR gear worked to the same degree as other strike aircraft without ATARS. On behalf of the Marines in this operation, thank you for your hard work on a very, very difficult and under-funded program. You have delivered a system that made a significant impact on this squadron's success in combat. I am not overstating the case that your efforts saved lives and greatly enhanced our targeting success with very difficult target sets in Belgrade and Novi Sad." [120]

Synthetic Aperture Radar (SAR)

Near-Real-Time Processing of SAR Imagery to the F/A-18 Warfighter. An F/A-18 SAR mode was provided to the Navy and Marine Corps warfighter with the introduction to the WD developed OFP 13C SCS. This mode provides the user with standoff, under-the-weather imaging capability. Before this, the imagery was collected and processed post-flight; however, the potential exists for processing the imagery in near-real-time and displaying it in the cockpit. Real-time SAR processing is highly desirable for targeting and subsequent battle damage assessment by the same weapons platform. SAR has become one of the most powerful reconnaissance tools available because of its under-the-weather and standoff capabilities. WD F/A-18 IPT engineering personnel have been integral to the SAR development effort and, as a result, WD now has the expertise to develop a turnkey F/A-18 SAR system. WD is recognized by organizations outside of the Navy as a repository of expertise in the field of SAR. The U.S. and its allies realized during Desert Storm that intelligence

from visible-light and IR sensors is easily denied by an enemy. [123]

Tomahawk

Significant Role in Strategic and Tactical Target Destruction. In the early phase of the Kosovo conflict, Tomahawk played a significant role in both strategic and tactical target destruction and significantly lessened collateral damage. (1999) [122]

1,000 Tomahawks Fired. British and U.S. forces fired more than 200 Tomahawk missiles in support of Operation Allied Force, including the 1,000th Tomahawk tactical firing, as well as the first Tomahawks fired by the U.K. [121]

Weapon Platform Integration

AV-8B

Open System Core Avionics Requirement (OSCAR) Integrated Product Team (IPT) Achievements Major Milestone. WD is the system developer for OSCAR. The OSCAR program achieved a major milestone on May 29, 1998. A PowerPC-based Mission System Computer was used on board an instrumented AV-8B to complete a successful first flight of the OSCAR Iteration three OFP at the Land Range. The OSCAR project replaces two of the AV-8B major avionics components, the mission computer and the stores management computer, with open architecture systems based on industry standards, rather than the closed military-specific designs historically used. (1998) [124]

Direct Attack Munition Affordable Seeker (DAMASK)

DAMASK First Guidable Flight. The DAMASK Program began in 1998 and proved that GPS independent, through-the-weather precision strike could be provided at extremely low cost. DAMASK developed an image-based accuracy-enhancement kit for existing GPS/INS guided weapons and integrated that kit with JDAMs that were launched at targets off multiple platforms. Every weapon hit its target with less-than-1-meter accuracy. DAMASK generates a template from a target image—from satellites, reconnaissance aircraft, UAVs, or an aircraft's own sensors. The template, stored on the weapon, is generated automatically at selection of the desired impact point. After release, a weapon flies using an INS. DAMASK uses its infrared camera to image the target area, compares what it sees to the template, calculates navigation and target location errors, and updates the weapon's INS system. DAMASK is affordable because it uses commercial off-the-shelf components such as the uncooled focal plane array developed by Raytheon for General Motors Cadillac night-vision driver's aid and a very simple strap-down design. Low-cost optics developed by Elcan also reduced window cost by a factor of 100 by using a thin-film polymer instead of a heavy glass window, and the use of injection-molded dome composites reduced costs from $1,000 to just $50 each. Today, DAMASK technology is used in a wide variety of U.S. military applications. [125]

F/A-18

Urgent Software Update. The F/A-18 Advanced Weapons Laboratory (AWL) responded to a request from PMA-265 and the JDAM team to make changes to F/A-18 software in support of Marine squadrons deploying to the Balkans. This urgent program culminated in a successful combined AWL/VX-9 JDAM launch, and the software was formally released late in May. WD personnel briefed in-theater aircrew and maintenance personnel on the software changes. [122]

Rapid Precision Targeting (RPT)

Controlled Reference Image Base (CRIB). Processing time greatly reduced. During Kosovo, WD's RPTS team was tasked to prepare a CRIB, a geo-referenced digital database consisting of highly accurate terrain files and images. Time was of the essence and the task required extensive processing of a precision digital database developed by the National Imaging and Mapping Agency. However the team's computers would have taken 2.7 years to prepare the Kosovo CRIB. The China Lake High Performance Computing Distributed Center made its Silicon Graphics, Inc. Onyx2 Infinite Reality Monster computers available to process CRIB data on nights and weekends, cutting development time to four months. [54]

National Reconnaissance Office (NRO) Awards Received. Five China Lake engineers received awards from the NRO for "Exceptional performance and outstanding contributions in support of the Kosovo war effort." The team and their RPTS were credited with giving pilots "the critical life-saving advantage of real-time information in the cockpit, which enabled them to attack mobile targets within a 5- to 10-minute period." [54]

Sensor to Shooter (Time-Critical Targeting Packages). During the air war in Kosovo, it was not unusual for an allied pilot in the midst of a mission to receive an urgent message redirecting the aircraft to a time-critical target. That target might be a threat convoy, a mobile artillery unit, or an aircraft temporarily camouflaged at a remote airfield. On the cockpit digital display indicator, the pilot would receive a new targeting package consisting of target coordinates, timely imagery, annotated maps, and other pertinent information. The process of rapid precision targeting is part of the larger sensor-to-shooter scenario that involves identifying a potential target, obtaining strike authorization, preparing a targeting package, and transmitting that package to a strike pilot in the area. [54]

Test and Evaluation/Range Support

Bomblets Test

Short-Turnaround Test. British Harriers, Tornados, and Jaguars carried out a critical short-turnaround test program of the CBU-87 combined-effects munitions and BLU-97 bomblets on the Land Range in support of Kosovo operations. (1999) [122]

Electronic Combat Range (ECR)

Tempo Increased. At the ECR, the tempo of operations increased dramatically. Fleet, Marine Corps, Air Force, Allied, and individual weapons programs conducted testing and training in direct support of the Kosovo operations. [122]

F-14B

Acceleration of Operational Testing. VX-9 Point Mugu conducted OT of OFP 320 (the radar tape load) for the F-14B aircraft. NWTS Point Mugu and VX-9 maintenance departments combined into one unit to complete work two months early, allowing an East Coast aircraft carrier with VF-102 (F-14B squadron) to deploy several months early. [120]

Accelerated Test Schedule. During OT and evaluation of the F-14B's Upgrade OFP with GPS/INS capabilities, Air T&E Squadron Nine (VX-9) received word to accelerate the test schedule. This was necessary to support the early deployment of a Carrier Battle Group to the conflict in Kosovo. WD responded with priority range periods and target support for six sorties, resulting in early completion of the test program. [122]

F/A-18E/F

More Than 200 Flight Tests. WD pilots flew more than 200 developmental and operational flight tests of the F/A-18E/F Super Hornet, including the first live-ordnance delivery from the Super Hornet and the first dual HARM launch from any F/A-18. (1998) [126]

Italian Navy

Response. NAVAIR team members provided a rapid-response team to the Italian Navy in response to operational EW requirements. The success of this team allowed the Italian Navy AV-8Bs to fly multiple missions in support of allied Kosovo operations. [121]

Rolling Airframe Missile (RAM)

Scores Direct Hit on a Supersonic Diving Target. WD RAM Test Team successfully conducted a RAM Block 1 missile flight against a diving MQM-8G Vandal drone target on the Sea Range. During the dive, the target transitioned to terminal homing on an active beacon located on a barge being towed 300 feet behind the Self Defense Test Ship (SDTS). Representatives from the RAM project office, Development Operational Test and Evaluation (DOT&E), and Commander, Operational Test and Evaluation Force (COMOPTEVFOR) witnessed this first RAM DT/OT test. (1999) [123]

Tomahawk

First Successful Tomahawk Launch by a British Submarine. After more than a year of planning and preparations, the WD Tomahawk Test Team successfully completed the Tomahawk British Flight Test Program. This program consisted of a series of three launches of the U.K. Tomahawk missile from a U.K. submarine. All of the launches took place on the Sea Range; two inert warhead missiles flew inland to China Lake and one warhead-equipped missile flew to an impact on San Clemente Island. Because of the International linkages in this program, these tests drew a high level of interest. Many senior officers from both the USN and the British Royal Navy were present to observe the final test. (1999) [123]

Significant Role in Strategic and Tactical Target Destruction. In the early phase of the Kosovo conflict, Tomahawk played a significant role in both strategic and tactical target destruction and significantly lessened collateral damage. (1999) [122]

Electronic Warfare

Chaff Dispenser

WD supported allied customers, including an urgent requirement from the Netherlands for a P-3 chaff dispenser, associated software, and the required expendables. This requirement enabled the Netherlands to join forces with the U.S. in support of the Kosovo operations. [121]

Electronic Warfare Database Support (EWDS)

The WD EA-6B EWDS Team responded to Fleet requests for ALQ-99 and HARM data in support of Operations Allied Force (78 requests) and Northern Watch (18 requests). EWDS also released the FY99 third-quarter products to the EA-6B Fleet and joint Navy, Marine, and Air Force community on May 25, 1999. The EWDS Fleet products included EA-6B mission data tapes, tactics guides, a database browser, archived database reports, software trouble report database browser, emitter parameter library browser, and other products. EWDS defined and refined processes, development tools, requirements, and design for the next generation of the EA-6B Tactical Information and Report Management System (ETIRMS) software suite. EWDS continued development with programmers to provide a rapid reprogramming capability. This capability allowed EWDS to rapidly reprogram the EA-6B planner with the latest threat data over SIPRNET channels. [120]

Electronic Intelligence (ELINT) Files

New ELINT Files Provided to Deployed Units Three Months Ahead of Schedule. Electronic Intelligence (ELINT) is information received from signals collected from radars or other transmitting devices. In the case of radars, the signal is made up of pulses transmitted at a given radio frequency, pulse repetition frequency, and pulse duration. The collection of pulses can be used to identify the transmitting radar system. Receivers like those contained in Anti-Radiation Missiles (ARMs) use this ELINT information to identify and track their target radars. When a new waveform is transmitted from a radar, that information needs to be programmed into the ARM system so the new signal can also be tracked successfully. Since the early 1990s, when new radar signals were correlated to geographic areas of interest (based on world events), this new information was analyzed and programmed into the correct format to allow HARM to be used against these new targets. The HARM office distributed geo-tailored ELINT to the deployed squadrons, shore-based Marines, and the weapon

schools, allowing HARM to be used against new or modified threat radars. This proactive response driven by real-world events allowed deployed squadrons to quickly respond to the changing environment. This rapid response greatly supported the efforts during Allied Force. The HARM team continues to respond to developing confrontations with the timeliest information available in anticipation of their weapon being the first into the target area. [166]

Escorted Every Strike Group

A star performer during the Kosovo operations was the EA-6B, which escorted virtually every strike group while performing jamming and employing HARM against hostile radars. In support of the suppression of enemy air defense mission, WD's EA-6B WSSA, ARM IPT, and TACAIR EW IPT responded to more than 100 Fleet requests for ALQ-99 (the radar jammer used on the EA-6B aircraft) and HARM data. [122]

P-3 Pods

Point Mugu worked with the P-3 community to provide self-protection against surface-to-air threats. Mugu designed and developed the aircraft interface, upgraded the pod to successfully perform on the P-3, performed a quick-look flight test, and deployed to Sigonella, Italy, to install the system and train both maintenance and aircrew on the pod. WD deployed twice to Sigonella for follow-on training to other squadrons. [127]

Direct Fleet Support

Fleet Weapons Support Team (FWST)

FWST Support. At Point Mugu, the FWST provides on-site/on-call engineering, logistics, and technical support on Naval Aviation weapons and weapons systems. The objective is to provide a closed-loop feedback system for timely resolution of Fleet problems. FWST members, located around the world at major Navy and Marine Corps installations, provide support to organizational- and intermediate-level maintenance personnel in aviation units and to ship and station ordnance forces. FWST is directly involved in many Fleet ordnance-related programs. During Kosovo, FWST provided personnel to support forward units for approximately 30 days. Pre-Kosovo support efforts included the P-3 deployment of SLAM/SLAM-ER. [128]

Joint Standoff Missile (JSOW)

Support Provided In-Theater. *USS Kitty Hawk*. WD personnel traveled to *USS Kitty Hawk* (CV-63) deployed in the Northern Arabian Sea in support of Operation Southern Watch, where they provided JSOW initial training for WD and Carrier Air Wing Five. Briefings and lectures were given to the aircraft crash crews, *USS Kitty Hawk* EOD Detachment, Kuwait Beach Detachment, Catapult Officer and crew, CAG Commander, and the Captain of *USS Kitty Hawk*. Teams provided technical support during aircraft loading evolutions, weapons receipt inspections, underway replenishment, vertical replenishment, helicopter onboard delivery, and un-canning and re-canning of assets. Weapons receipt inspection, reprogramming, and built-in-test were performed on 12 assets received from *USS Carl Vinson* by *USS Kilauea* ammunition supply ship. (1999) [120]

Support Provided In-Theater. *USS Theodore Roosevelt.* Members of the JSOW IPT supported *USS Theodore Roosevelt* off Kosovo and *USS Kitty Hawk* (deployed in the Northern Arabian Sea in support of Operation Southern Watch). (1999) [122]

***USS Carl Vinson*.** WD directly contributed to the success of Operation Allied Force in Kosovo and in Southwest Asia. With less than 10 days notice, WD transported JSOWs from the U.S. to the Persian Gulf, and from there, weapons and support personnel from China Lake were transferred to *USS Carl Vinson*. WD assisted aircrew with last minute updates to operational software. A few days later, JSOW was successfully used in combat. The lethal effectiveness of these weapons was reconfirmed only days after the Navy declared JSOW operational—a phenomenal effort. [121]

Marine Corps Support

USMC Support. The Pacific Test Wing coordinated activities with VMFA-332 on JSOW, JDAM, and HARM to support a potential deployment by a MAG-31 F/A-18D squadron. This was followed by an onsite briefing of OFP 13C and related weapons JDAM/JSOW/GBU-24 at Beaufort, South Carolina, the week of April 5. MAG-31 requested a similar set of briefings for all MAG-31 units at home preparing for overseas assignment. This support was provided during the week of April 19 to ensure that the units were up to speed on the systems available to them. [120]

Standoff Land-Attack Missile (SLAM)

Planning Equipment. At the request of Wing Five Commodore, WD supported VP-10, on deployment in Sigonella, Italy, as it continued to fly armed missions around the clock in that theater. WD hand delivered SLAM mission-planning equipment at the request of the P-3 Class Desk at PMA-290. WD evaluated the support equipment for both SLAM and Maverick missiles and recommended two additional AWM-92 test sets be put in place. [120]

USS Roosevelt

Urgent Training Request. WD team members responded to an urgent training requirement from *USS Roosevelt*. An EA-6B squadron from Whidbey Island, Washington, which had been unable to meet its training requirements before embarking aboard *Roosevelt*, requested support from the Sea Range. The squadron flew a HARM exercise, complete with live firings, and was therefore better prepared to attack targets when it deployed to the Adriatic Sea. [121]

VAQ-141

Provided Threat Information. WD worked with the National Air Intelligence Command on issues regarding information from the national sensors on a certain threat issue in the Former Republic of Yugoslavia and relayed the information to VAQ-141. [120]

OPERATION DESERT FOX (1998)

Weapons and Weapon Systems

High-Speed Antiradiation Missile (HARM)

Seven HARM Missiles in the Air Simultaneously in Fleet Battlefield Exercise Echo. VAQ-131 and VAQ-139, with a total of three aircraft, participated in the HARM portion of the exercise. The main objective of FBE-E was rapid retasking and retargeting of aircraft with the Joint Targeting Workstation (JTW) and target imagery and passing the information electronically. The primary HARM shooter received his information through his improved data modem (IDM). He then passed the information to the other two aircraft and all three fired their missiles (AGM-88C, AGM-88B, and AGM-88A). This is the first time that 88A, 88B, and 88C missiles were airborne together. The primary shooter moved out, and approximately 15 seconds later two more missiles were fired (AGM-88A); then 15 to 20 seconds later the final two were fired (AGM-88A). Seven missiles were in the air at one time. (1999) [123]

Joint Standoff Weapon (JSOW)

JSOW Integrated Product Team (IPT) Participates in Rapid Response to Operation Desert Fox. CAGs deployed in support of Operation Desert Fox, in conjunction with Commander, Naval Air, Atlantic (COMNAVAIRLANT), urgently requested some of the first production JSOW AGM-154A assets in support of operations. To support this decision, a WD quick-response team was formed and, on January 6, 1999, reprogrammed JSOWs with software appropriate to the CAG receiving the weapons. The AGM-154As were part of the first low-rate initial production units that Raytheon Systems Company delivered under contract. [123]

Provided JSOW Experts to Carrier Air Group (CAG). WD also led the effort to provide JSOW subject-matter experts to the CAG. Personnel provided weapons training and hand-carried mission planning and weapons application software for use with the weapons. [123]

High-Level Navy Recognition. The JSOW rapid-response effort was recognized at the highest levels in the Navy—including Office of the Chief of Naval Operations (OPNAV), COMNAVAIRLANT, and the Combat Commander-in-Chiefs (CINCs)—and was viewed as an amazingly rapid-response effort. The WD JSOW team made significant contributions in rapidly identifying requirements, reprogramming weapons, and preparing plans to support the CAG's training and weapon operations. The JSOW team successfully addressed many logistical, software, security, and travel challenges. (1999) [123]

Weapon Platform Integration

Advanced Weapons Laboratory (AWL)

Conducts First F/A-18 Mixed Weapons Load. Responding to requests from VX-9, the AWL conducted tests to verify compatibility of flying a mixed load of MIL-STD-1760 air-to-ground weapons. The Avionics Test Bed flew a mission with JSOW and JDAM stores, using 13E software. This was the first DT flight of mixed air-to-ground 1760 weapons conducted with the F/A-18. The aircraft was configured with a JSOW loaded on the left midboard (BLU-97 variant) and inboard (BLU-108 variant) station, and a JDAM (BLU-109 variant) loaded on the right midboard station. VX-9 provided the JDAM asset used in the test, which was the first time multiple types of weapons were used on same mission. In particular, it proved the ability to fly with one weapon type selected as the primary weapon while keeping others "background selected" (power applied). Changing weapon types in-flight without additional warm-up time is a significant benefit to the Fleet user; the weapons are available as soon as they are selected. The flight demonstrated a capability to perform a soft kill with JSOW from a long range, followed by a hard kill with JDAM at a closer range. (1998) [123]

F/A-18 AWL Rapid Response. A rapid response was provided to deployed forces onboard *USS Nimitz* on station in the Persian Gulf. The response provided military technicians with new maintenance tools designed and built by F/A-18 Facilities Task Team personnel. Engineers designed a radar calibration collection module that allowed maintenance personnel to monitor and record calibration data stored in the radar. The calibration data acquired during the test could then be downloaded to a format that could be transmitted anywhere

in the world using existing communications links for further analysis. [124]

Test and Evaluation/Range Support

High-Speed Antiradiation Missile (HARM)

Missiles Against Two Targets. In a first-time-ever maneuver, a F/A-18E/F Super Hornet (F2), flying over the Land Range, fired two HARM missiles sequentially, each hitting their respective targets. It was the first full-system live-fire test of the F/A-18E/F program with forward-firing ordnance. The radars used during the test simulated SAM systems similar to those used against U.S. and Allied forces during the Gulf War. Commenting on the significance of the test, the F/A-18 Integrated Program Team Deputy said, "This is the first airplane that will be able to suppress a threat itself, then follow up with a hard kill on that same threat or a target in the vicinity. The aircraft simultaneously engaged two separate targets and still had the ability to carry additional weapons on the four other wing stations. The increased firepower of E/F will allow joint force commanders to engage far more targets on each strike resulting in faster, more decisive victories." (circa 1998) [123]

Rolling Airframe Missile (RAM)

First Dual Development Test (DT) Launch. WD successfully conducted the first dual DT launch of RAM Block 1 missiles against an MM-38 Exocet target on the WD Sea Range. A very large hazard pattern of over 2,000 square miles was cleared of all ocean traffic before launch. Air support for the operation was provided by the NWTS, Point Mugu. (1998). [123]

Successful Tests Conducted. Development testing continued with several successful intercepts of difficult targets (diving, supersonic, dual targets, maneuvering). Two RAM missiles were successfully launched against a Harpoon missile launched as a target from an F/A-18. The Harpoon targeted a barge towed behind the Self-Defense Test Ship. (1998) [123]

Crew Systems

Aircrew Safety

Helo Squadron HMLA-267 Outfitted with Latest Body Protection. A WD team outfitted a U.S. Marine Helicopter Squadron, HMLA-267, with the latest protective body armor, survival vests, and life preservers. The team consisted of personnel from WD China Lake, Naval Air Warfare Center Aircraft Division (NAWCAD) Patuxent River, and the Fleet Air Introduction Liaison of Survival Aircrew Flight Equipment (FAILSAFE) teams. The new system consisted of the Aircrew Survival Soft Body Armor, A/P22P/-18(V); Hard Body Armor, PRU-60A/P22P-15; the Survival Vest, CMU-33/P22P-18; and the Low-Profile Floatation Collar, LPU-34/P. Altogether, 85 new body armor assemblies, survival vests, and LPU-34s were custom fitted and placed into service by the team and U.S. Marine maintenance personnel of MALS-39 and HMLA-267 (Marine Air-Ground Task Force (MAGTAF)) from February 13 to 17, 1998. [124]

Low-Profile Floatation Collars

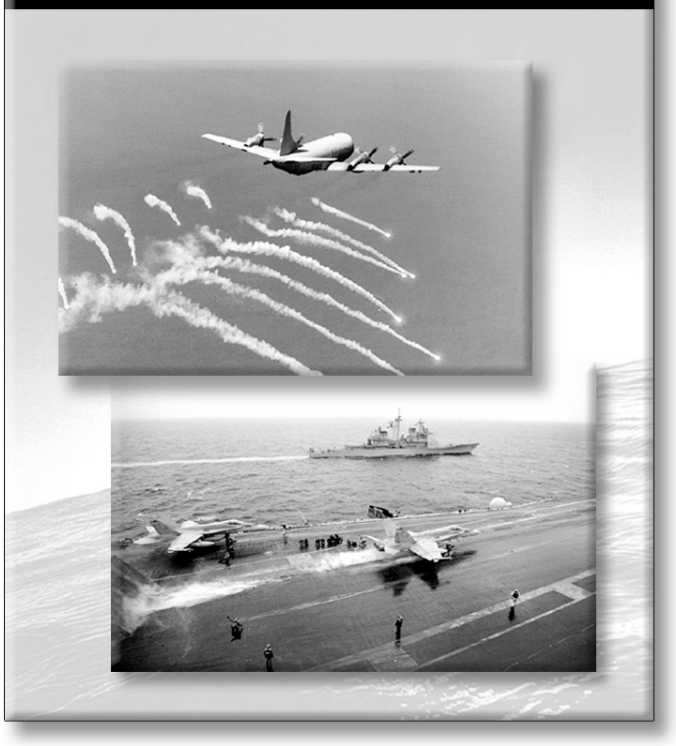
The NAVAIR Crew Systems Department developed a new survival vest and floatation collar that are now the primary life preservers for USN aircrews. In 1997, WD initiated a program for the floatation collar and open competition resulted in a sole source contract with Safety Equipment International of Asheville, North Carolina. The qualification program produced the LPU-34/P, LPU-36/P, and the LPU-37/P Low Profile Floatation Collars. They provide 65 pounds of buoyancy, auto-rotate the aircrews face out of the water, and mount to the torso harness and all survival vests. Collars weigh only four pounds each. The project was the Crew Systems Department's first IPT team project under the new acquisition guidelines. The vest was developed at Patuxent River and the Collar was developed at WD. The program was so successful that it was used as a model for future Aviation Life Support Systems (ALSS) teams. The program went from concept to production in 18 months, and the first product was delivered to the USMC 22 months after the program start. [129]

Direct Fleet Support

Joint Standoff Weapon (JSOW)

WD played a significant role in the successful delivery of the first JSOW. The Division's IPT oversaw the development of the JSOW and prepared the Fleet for its introduction and operational use. The team, including Raytheon Systems Company members, delivered the first three JSOW missiles to the Navy in May. (1998) [126]

BOSNIAN CONFLICT (1992–1995)



Weapons and Weapon Systems

Fuzing Systems

WD developed new warhead and fuze for Tomahawk Block III. This was the first time WD used a reactive case warhead. These warheads were later used in Kosovo, Desert Storm, and Operation Enduring Freedom. (circa 1992) [71]

Targeting

NATO Medal for Rapid Precision Targeting System (RPTS) Cell in Vicenza, Italy. During the Bosnian hostilities, an RPTS cell was set up at Vicenza, Italy, to assist Allied air operations. WD developed the software for the complex communications suite necessary to integrate the cell into theater operations. For two and a half years, WD personnel lived in Italy and ran the cell, a feat recognized with letters of recognition from two generals as well as the NATO medal. [54]

Weapon Platform Integration

AH-1

OFP Software Deployed. First OFP software update for deployed AH-1W helicopters. (circa 1992) [46]

AV-8B

Software Delivered. OmnibusVII software delivered to the Fleet. (circa 1992) [46]

Test and Evaluation/Range Support

Full-Up Tests

The first ever joint live-fire full-up tests were completed on F/A-18, AV-8, and F-15. (circa 1992) [46]

Research, Science, and Technology

Continuous Emissions Monitor

The TraceAIR™ system was developed to answer an environmental need to monitor pollution from the primary 14 toxic airborne metals frequently emitted from incinerator stacks. A CRADA between NAVAIR WD China Lake and Thermo Jarrell Ash Corporation (TJA) was formed and the project was developed, tested, and validated as a viable commercial environmental monitor. In 1997, the TraceAIR™ CEM system was recognized as a winner of one of the prestigious R&D Magazine R&D 100 Award. These awards recognize the 100 most technologically significant new products of the year and have been referred to as the "Oscars of Invention" and the "Nobel Prize of Applied Research." The inventors were also awarded a 1998 Award for Excellence in Technology Transfer by the Federal Laboratory Consortium (FLC). (1997) [130]

Exploding Foil Initiators (EFI)

China Lake developed the Low-Energy Exploding Foil Initiator (LEEFI) used in line with main-charge explosives to safely initiate warheads. The LEEFI employs microelectronics technologies that require only half as much energy as conventional initiators, and production is two thirds less labor intensive; 600 (versus 100) can now be produced at one time. Costs have dropped from $200 to $75 per initiator, providing significant savings for high-volume usage in lower-cost weapon systems. LEEFI development, which began in the early 1990s, required several years to successfully initiate an explosive charge. Proper firing was optimized, and by 1996 the design was qualified for in-line use in DOD weapon systems. In 1997 an improved-barrel LEEFI was perfected. In 2003 the LEEFI is the lowest-energy EFI in production and used in a large number of DOD weapon systems, including AIM-9X, ESSM, Standard Missile, GLMRS, LOCASS, RAMS, JAMI, and JSOW. LEEFI technology is evolving and future applications include a new in-line rocket motor igniter and a design with an integrated switch to significantly reduce system cost and volume. A high-volume (three million), extremely low-cost design ($10) is also under way for the Army. A multipoint array for an Air Force program is in progress, and a low-cost multipoint line generator is being proposed for the Standard Missile. WD also developed a new high-performance (HIPER) secondary explosive, RSI-007. Working with contractors, the team has created HIPER EFI, which is hermetically sealed and directly cast into the warhead fill with an operational life of 40 years. As a result of improved insensitive munitions qualities and more affordability, HIPER EFI will transition to artillery and other

low-cost applications. HIPER EFI was qualified in 2002 and has produced a family of initiators with the same input energy requirements as the LEEFI. Explosive output was increased by 50%, with a 30% reduction in cost. The explosive composition is being used to develop a new family of low-cost non-hermetic initiators with an expected 80% reduction in production cost. [131]

Multi-Mission Propulsion Technology Advanced Technology Demonstration (MMPT ATD)

The program objective was to demonstrate significant increase in missile performance by integrating technology advancements in solid-propellant pulsed rocket motors, integrated aerodynamic and thrust vector controls, and composite structures and materials for the rocket motor case and control fins. The MMPT ATD program used an 8-inch-diameter airframe to demonstrate these technologies. The program began in FY92 and culminated in FY95 with three vertical ground-launched flight tests to validate the technologies. China Lake developed the autopilot, performed the system integration function, and provided the range for the ground-launched flight tests. Benefits from the technology demonstrated include advances in energy management, maneuverability, and insensitive munitions. During the three ground-launched flight tests, the MMPT ATD program demonstrated an alternative to compromises by providing the missile designer with thrust management, including thrust vector control. Such flexibility will permit trading of speed, range, and maneuverability to address a broader range of targets. [132]

Nano-Scale Metal Powders and Reactive Composites

WD scientists work continuously to devise more powerful energetic materials (explosives and propellants) and to tailor these materials to specific warhead, propulsion, and pyrotechnic systems. Metal fuels, such as aluminum and magnesium, are used in many propellant formulations, flares, countermeasures, and explosives. One area of intense research is nano-scale metals and composites—small-dimension materials (less than 100 nanometers (nm), or 1 10-millionth of a meter). In the mid-1990s, WD scientists found that fine-grain (150 nm) metal powders developed in Russia were capable of increasing propellant burn rates by two to three times and enhancing detonation velocities in explosives. WD developed and patented a new solution method for preparing fine-grain aluminum powders (50 to 500 nm). In collaboration with Los Alamos National Laboratory, WD also patented lead-free percussion primer mixes based on metastable interstitial composite (MIC) technology—nano-scale composite mixtures of an ultra-fine metal fuel and an oxidizer. These primer mixes could replace conventional ammunition primers that use either lead azide or lead styphnate, toxic materials that cause neurological, gastrointestinal, reproductive, and renal damage in humans. WD's current research on the aging and prevention of aging of nanoscale metals and composites will enable the deployment of weapon systems with nano-scale energetic components. Nano-scale materials also have an enormous potential in electronics, biomedical applications, and microelectronic machines. [133]

DESERT SHIELD/STORM (1991)

Historical Note

In 1992 China Lake and Point Mugu merged, becoming WD under NAVAIR. Therefore, entries from Desert Shield/Storm back to WWII are either China Lake or Point Mugu entries.

The Naval Weapons Center (NWC), China Lake, began the 1990s with significant support to Operation Desert Storm. True to its heritage, NWC was ready with quick-reaction, on-demand efforts to support the operating forces; many of these efforts were conducted in concert with the operating forces and with other Navy activities. The Center conducted efforts that modified, improved, tested, and validated various aspects of Sidewinder, Tomahawk, FAE weapon, HARM, and Shrike weapon systems to meet the immediate needs of the troops in the Gulf.

NWC developed electronic-warfare system upgrades, developed and hand-delivered OFP upgrades, and developed and fielded new/improved weapon-integration and -targeting software for combat aircraft, including the F/A-18, AV-8B, A-6E, and F-14. Major flight-test support was provided for Navy and Air Force squadrons, especially using China Lake's electronic-warfare threat-environment simulation at Echo Range [now the Electronic Combat Range (ECR)], to help validate and update avionics and tactics.

A variety of threat-analysis tasks, including weapon survivability and vulnerability analyses, were also conducted and supported by the Center to help ensure maximum effect with minimum attrition. NWC also supported efforts to protect Allied forces against the potential use of chemical weapons by Iraq. Numerous small quick-reaction projects were conducted in support of various aspects of the combat operations; many of these projects were aimed at improved aircrew safety.

Weapons and Weapon Systems

Fuel-Air Explosive (FAE)

Weapons Sent to the Marines. During Desert Shield, the Marine Corps asked for a China Lake-designed FAE weapon that is particularly good for clearing mine fields. The weapon was designed for use in Vietnam, but China Lake called on one of the original designers who quickly tested the reliability of the older weapons for use in Desert Storm. Weapons were then sent to the Marine aviation squadrons. Actual use is not confirmed. (circa 1991) [49]

Fuzing

Using Older Inventory. China Lake quickly completed a series of laboratory and flight tests to evaluate the usefulness of the Navy's existing bomb fuze inventory. Testing proved that if the older fuzes were used in conjunction with newer fuzes, the combination would be safe and effective. Consequently, a large inventory of existing older fuzes was cleared for quick use in Desert Storm. [49]

Gator

Increased Gator Weapon Delivery by a Factor of Four. After two months, a sufficient number of weapons were delivered to satisfy Marine Corps requirements. Because of these efforts, Gator was available and performed well in limiting the mobility of the Iraqi Army, playing a key role in Desert Storm. (circa 1991) [49]

Test and Evaluation/Range Support

F-14 Phoenix

Tomcat Six-On-Six Test. Testing of the improved AIM-54C began at Point Mugu in 1979, about the same time that the Iranian revolutionary forces were taking over the F-14A and AIM-54A equipment in that country. This necessitated a crash program at Point Mugu to develop counter-countermeasures that would defeat the AIM-54, and to ensure that the new F-14A/AIM-54C could not be compromised by the earlier system. The operation was preceded by several weeks of preparation involving more than 500 people. Point Mugu development testing included a spectacular six-on-six test before a congressional committee. The test demonstrated that the weapon system could simultaneously acquire and track six independent targets, and then launch and guide six missiles, each to a selected target. [135]

Standoff Land-Attack Missile (SLAM)

First Launch From A-6E Intruder. The first launch of an AGM-84E SLAM from a Point Mugu A-6E Intruder was conducted in 1989 in a pre-planned mission against a simulated tactical mission communication site on San Nicolas

Island. Even though SLAM was still undergoing operational evaluation at Point Mugu, SLAM was sent to the Persian Gulf for Operation Desert Storm. Seven SLAMs were launched at high-priority Iraqi targets. These images were shown on national TV as the SLAMs flew into the targets. (1989) [136]

Tomahawk

First Submarine Launch—Desert Shield/Storm, Persian Gulf. Tomahawk developmental flight tests and laboratory simulations and evaluations began at Point Mugu in the mid-1970s, and in 1978 the first submarine launch of a Land-Attack Tomahawk was made off Point Mugu. Initial Operating Capability for the weapon came in 1983. During the Persian Gulf War in 1991 and subsequent encounters in that arena, Tomahawk performed just as it had been designed to do. (1970 - 1991) [136]

Electronic Warfare

ALQ-167 Electronic Countermeasures Pod

Tactical Pod Upgraded. Point Mugu developed the upgrade technique, then designed and produced the required hardware. Technicians went to deployed carriers (Persian Gulf and Red Sea), Marine air forces based in Bahrain, and carriers based in CONUS and Japan to install the upgrade and optimize the system. The time it took to develop and test the technique and install the upgrade in the Middle East was four weeks. The ALQ-167 was used by Fleet forces (especially at night) and was found to be very effective. [127]

Radar

Countering Iraqi Radar. The EA-6B Division (Point Mugu) found itself running against a tight deadline in its efforts to adapt the aircraft to the new Block III and IV HARMs. "There was a radar in Iraq that was giving us a problem. So we took a contractor-developed pod, wrote some software which allowed us to integrate that pod with the current EA-6B, and got the thing deployed in time," according to the associate director (programs). [137]

Successfully Countering Iraqi Radar. Before the first Navy fighters and bombers joined in air strikes over Iraq, scientists from Point Mugu reprogrammed aircraft computers with fresh intelligence to elude Iraqi radar. Military analysts say mastery of such "electronic warfare" has helped U.S. aircraft make thousands of bombing runs over Iraq with remarkably few casualties. After the initial attack by cruise missiles and Stealth bombers, "electronic warfare allowed the rest of our aircraft to penetrate with impunity," said Jeff Shaffer, a political-military analyst with the Center for Strategic and International Studies in Washington. The combination, he said, "was a spectacular success, given the lack of casualties." [138]

Reconnaissance

Tactical Electronic Reconnaissance Processing and Evaluation System (TERPES). Tactical Orders of Battle. The Marine Corps Projects arm of the EA-6B Systems Division at Point Mugu also made their mark in Kuwait. One of its major contributions was the TERPES, which updated and maintained tactical orders of battle in near-real time. [137]

Tactical Software Support

Prowler Software Tapes/Successful Strikes. In 1973 Point Mugu was designated as the Tactical SSA for the EA-6B, the first major EW system to be provided life-cycle software support. The Weapon System Support Laboratory developed software tapes that were an essential element of the success of strike aircraft during the 1986 operations in Libya and the Persian Gulf War of 1991. [139]

Threat Files

Working quietly but frantically behind the scenes, a team of China Lake personnel reprogrammed the HARM seeker to recognize the unique characteristics of targets in combat. A list ("threat file") is contained in the Command Launch Computer (CLC), a memory device. Normally the CLC is loaded with a "global file" containing signal characteristics of radar systems from all over the world. As soon as Iraq invaded Kuwait, it was apparent that the CLC had to be adapted because Iraq had purchased a combination of military equipment from a variety of countries other than the Soviet Union. China Lake went to work defining a new "geo-tailored" threat file, tested it in the anechoic chamber, loaded the software into VX-5 attack aircraft, conducted flight tests, prepared an entire package of updated files, including users manuals, and delivered the software to aviation squadrons on their way to the Red Sea. Because the material was classified, engineers had to sleep with it on taxiways in the Persian Gulf area until secure delivery could be made. In addition, Point Mugu engineers updated the threat files of the ALR-67 Radar Warning Receiver (RWR) and the ALQ-126 jammer in time for use in the conflict. [140]

Research, Science, and Technology

Electronic Devices

Thin Films. A new process for producing high-quality, high-resistivity thin films of aluminum oxide on electronic material surfaces was discovered by China Lake scientists. This discovery may allow the implementation of high-speed gallium arsenide electronic devices in numerous military applications. (circa 1990) [141]

Direct Fleet Support

Fleet Weapons Support Team (FWST)

Desert Storm/Desert Shield. 150-Day Support. At Point Mugu, the FWST provides on-site/on-call engineering, logistics, and technical support on naval aviation weapons and weapons systems. The objective is to provide a closed-loop feedback system for timely resolution of Fleet problems. FWST members are located around the world at major Navy and Marine Corps installations. They provide support to organizational- and intermediate-level maintenance personnel in aviation units and to ship and station ordnance forces. FWST is directly involved in many Fleet ordnance-related programs. During Desert Storm/Desert Shield, FWST provided six personnel to support efforts for more than 150 days. [128]

Weapons/Weapon Systems

Weapons/Weapon Systems. Point Mugu and China Lake responded with quick-reaction, on-demand requests to support operating forces and troops in the Gulf. Engineers modified, improved, tested, and validated various aspects of the Sidewinder, Tomahawk, FAE, HARM, and Shrike weapon systems. Point Mugu developed EW system upgrades, developed and hand-delivered OFP upgrades, and developed and fielded new/improved weapon-integration and -targeting software for combat aircraft. [167]

Tomahawk Block III Ordnance Section

In 1991, China Lake was tasked to develop a new ordnance section for the Block III Tomahawk. The goal was to reduce the payload weight without reducing target effectiveness so that more fuel could be added to extend the missile range. China Lake answered the call by designing a new titanium reactive case warhead. The new ordnance system consisted of the WDU-36/B Warhead, BBU-47/B Fuze Booster, and FMU-148/B Fuze. The design was also optimized to meet Insensitive Munitions (IM) requirements and to improve target penetration. To test the new warhead and directly compare its performance to the old 1,000-pound warhead, two closed volume tests were conducted in an abandoned oil shale mine in Colorado. A 1,000-pound warhead, with the existing case, was detonated and detailed measurements were taken. Next, the same test was again conducted, this time with a 700-pound warhead with the new titanium case. This test allowed engineers to measure the total energy generated by the warheads. Results proved that the new WDU-36/B warhead's performance was comparable to the existing larger warhead. In addition, the titanium case was about 300 pounds lighter which allowed more fuel, increasing the range of the missile. To further enhance the effectiveness, China Lake developed a dual delayed fuze that allowed the user to select one of two penetration depths. To improve the IM performance, a stress riser groove was included on the warhead case so that in a fast or slow cook off environment the case would split open due to the pressure rise inside the case and relieve the confinement of the explosive material before it detonated. Lastly, the shape of the case was optimized to minimize ricochet, which improved the penetration capability of the warhead. [143]

Weapons and Weapon Systems

Advanced Common Intercept Missile Demonstration (ACIMD)
The ACIMD was a technology demonstration program intended to develop a concept for a long-range air-to-air missile system to replace the Phoenix missile. China Lake had been working with NAVAIR to demonstrate advanced missile technologies for a series of new weapons. One of those programs was ACIMD, which incorporated integral-rocket-ramjet propulsion, and airframe/steering technologies—which drew heavily on China Lake efforts. ACIMD tests demonstrated the technology and hardware for this highly advanced Sparrow-sized, multi-mode guided missile for the outer-air battle. China Lake began a three-year technology validation program in early 1982, with simulations and subsystem testing, intended to lead to hardware tests, including trials with complete guided missiles. The Navy planned to maintain and support an adequate Phoenix missile capability until the Advanced Air-to-Air Missile (AAAM), which incorporated ACIMD technologies, was fielded in sufficient numbers. A missile retrofit program incorporating an already developed and demonstrated block upgrade to the AIM-54C was a cost-effective interim solution. As of 1990, a minimum of 10 years was estimated as the amount of time required to introduce the follow-on AAAM. With the end of the Cold War, a general recognition was that the outer air battle—the battle against Soviet naval aviation bombers—was significantly reduced in importance. While AAAM was seen as the best defense against the Soviet naval air arm, the future threat would consist of Third World fighter-bombers or diesel-electric submarines. This changing security environment reduced the need for AAAM and the program was canceled in 1992. [144]

Advanced Interdiction Weapon System
NWC became the lead field activity for Advanced Interdiction Weapon System. (circa 1988) [46]

Advanced Bomb Family
NWC designated the lead field activity for Advanced Bomb Family. (circa 1990) [46]

Chaff Radar
Chaff-Characterization Radar was demonstrated. (circa 1986) [46]

Forward-Looking Infrared (FLIR)
A-7E FLIR. Targeting system was deployed for the A-7E FLIR. (circa 1978) [145]

FLIR. The FLIR-Based Night-Attack System was demonstrated. (circa 1975) [145]

Fuel-Air Explosive (FAE)
Catapult-Launched FAE system was demonstrated. (circa 1985) [46]

Solid FAE device feasibility was demonstrated. (circa 1987) [46]

Gator
Gator Scatterable Land Mine System released (use in combat not confirmed). (circa 1982) [46]

High-Speed Antiradiation Missile (HARM)
HARM became operational. (circa 1986) [46]

The Advanced Telemetry System for HARM was introduced to the Fleet on the A-7E. (circa 1986) [46]

Guns
GAU-12/U 25-mm gun and ammunition for the AV-8B was deployed. (circa 1984) [46]

Guidance and Control
Fighter/Attack Avionics Targeting Demonstration (F/AATD). Multisensor Tracker Algorithms. The F/AATD, completed in 1987, demonstrated multisensor correlation tracking for the F/A-18 aircraft in the air-to-air mode. This demonstration provided the basis for implementation of multisensor tracker algorithms in TACAIR operations. (1987) [141]

Radar
Portable Radar Jamming System Demonstrated. The EGGNOG system—lightweight, portable, broadband radar jamming capability for Marine Corps ground forces—was successfully demonstrated. (1982) [141]

Sidewinder

Sidewinder AIM-9M. AIM-9M became operational. (circa 1981) [145]

Combat Proven. The AIM-9M version was approved in 1981. In 1982 the -9L was successfully used by the British in the Falklands and by Israel against Syria. AIM-9L was proven in combat when Navy F-14 fighters downed Soviet-made Libyan warplanes over the Gulf of Sidra in 1981. [167]

Skipper

Skipper. The Skipper Laser-Guided Standoff Weapon Concept was demonstrated (circa 1981) [145]

Targeting

A-6E Tram. The A-6E Tram Targeting System was introduced to the Fleet. (circa 1980) [46]

Dual-Spectrum Seeker. The prototype Dual-Spectrum Seeker was demonstrated in the Sparrow Missile. (circa 1985) [46]

North-Finding Module. The North-Finding Module entered production. (circa 1985) [46]

QF-4. First night operation of full-scale aerial target (FSAT) (QF-4) was conducted. (circa 1988) [46]

QF-86F Full-Scale Aerial Target (FSAT). QF-86F FSAT became operational. (circa 1980) [145]

Thrust Vector Control (TVC)

Wave Of Applications. TVC technology for tactical weapons developed at China Lake was used in a wave of applications for a new family of vertically launched shipboard missiles: Tomahawk, Standard Missile, and the Vertical-Launch ASROC. TVC was also used for Agile and the Vertical Seeking Ejection Seat. (circa 1982) [141]

TNT-Detector

The Portable TNT-Detection Kit was developed. (circa 1984) [46]

Tomahawk

Principal Support Laboratory. NWC became the principal support laboratory for Tomahawk Cruise Missile. (circa 1982) [46]

Versatile Target Acquisition System

Development of the Versatile Target-Acquisition System was completed. (circa 1984) [46]

Vertical-Launch Antisubmarine Rocket (ASROC)

Successful Demonstration. The Vertical-Launch ASROC telemetry system was successfully demonstrated. (circa 1982) [46]

Weapon Platform Integration

A-6E. Software support for the A-6E aircraft was begun. (circa 1977) [46]

F/A-18 WSSA. NWC was designated as the F/A-18 WSSA. (circa 1976) [46]

Operational Flight Programs (OFPs)

OFP E-230. Software for the A-6E was released to the Fleet. (circa 1986) [46]

OFP 85A. Software for F/A-18 was released to the Fleet. (circa 1986) [46]

OFP. New OFPs for the F/A-18A/B and F/A-18C/D were introduced to the Fleet. (circa 1990) [46]

Omnibus V. Software for the AV-8B was fielded. [46]

Omnibus III. Software for the AV-8B was released to the Fleet. (circa 1984) [46]

Interoperability/Battlespace Integration

Interoperability and Battle Management

The Battle Management and Interoperability Center (BMIC) was established at Point Mugu in 1987. One early exercise included an Aegis engagement of nine hostile targets by nine missiles. A subsequent major multi-participant BMIC exercise included a simulated carrier command and control, guided missile cruisers and destroyers, ASW P-3s, simulated submarines, two Mobile Sea Range Targets, two electronic jamming B-52s escorted by four F-16s, and a QF-86. Also included were carrier air patrol and anti-air missions flown by F-14s and F/A-18s. Defensive forces were also presented with a simulated Soviet flotilla ready to strike from a remote area in the Channel Islands. [139]

Test and Evaluation/Range Support

AH-64

Apache/SideARM (AGM-122). Apache/SideARM (AGM-122) Missile Integration Demonstration was conducted. (circa 1987) [46]

Extended Area Test System (EATS)

Started in 1972 and completed in the early 1980s, EATS is a multilateral tracking system that operates over the horizon in a 250-mile radius around San Nicolas Island. Tracking up to 60 ships, aircraft, and targets from sea level to 100,000 feet, EATS can also relay drone control messages and transfer telemetry from up to 15 remotely controlled vehicles. Sixteen EATS ground reference stations and three instrumentation stations in an EP-3A aircraft communicate with instrumentation packages installed in drone targets, launch aircraft, and

ships participating in test exercises. The Multi-lateration Operations Control System (MOCS), a follow-on to the EATS, continues to use a large number of EATS assets, but is now primarily a GPS based tracking system. The MOCS supports approximately 250 operations per year with a majority of the tracked vehicles over the horizon from land based instrumentation. [167]

High-Speed Antiradiation Missile (HARM)
First live-guide launch of HARM from an A-6E was performed. (circa 1988) [46]

Sidewinder
A successful firing of BOA (compressed airframe Sidewinder) was conducted. (circa 1990) [46]

AIM-9R. AIM-9R was demonstrated in four successful firings. (circa 1990) [46]

Tomahawk
In 1977 Point Mugu was designated the lead test activity for Tomahawk and between 1978 and 1980 a number of significant firsts occurred: first vertical launch, first TLAM submarine launch, and first flight of Tomahawk airfield attack missile. The A-6 was also configured for launching Tomahawk. [135]

Trident Missile Test Instrumentation System
Selected in 1975 to build a Trident submarine-launched ballistic missile (SLBM) operational test range in the Pacific, Point Mugu designed and installed the Trident Missile Test Instrumentation System—the most complex and extensive range system ever assembled at Point Mugu. The system became operational in 1983 and provided test forces with range-safety displays, underwater submarine tracking, in-flight tracking of up to four missiles, instantaneous impact predictions, and recording and display of missile telemetry—all in real time. [136]

Electronic Warfare

AN/ALQ-126B
First Reprogrammable, Self-Protection Jammer. In 1982 Point Mugu was chartered as the EW Software Support Activity, tasked with developing, reprogramming, and managing deployed EW software. The Red Systems developed increasingly complex threat environments to match changing Soviet capabilities. The Blue Systems activities developed the AN/ALQ-126B, the first reprogrammable, active, self-protection jammer. Later versions were carried by most of the Navy's combat aircraft. Blue Systems have been widely deployed with the Fleet and used effectively in the Korean, Vietnam, and Persian Gulf wars. (circa 1982) [139]

Modeling and Simulation

Warfare Simulation Facility Aids Weapons, Tactics Development
From 1978 to 1997, China Lake maintained an interactive warfare simulation facility—the Weapons and Tactics Analysis Center (WEPTAC)—allowed users to make battle decisions in a limited information environment, pitted against opposing threat systems controlled by intelligence experts. Simulations were mostly tactical and did not encompass strategic scenarios. WEPTAC was used to perform missions as small as one-against-one air engagements up to larger situations involving entire battle groups including air-to-air, antisurface, and antiair warfare aspects. The early concept was to see if an interactive simulation facility could be based on minicomputers and developed at a low cost. The system grew from a small prototype to an advanced system that was capable of modeling up to 1,200 aircraft or ship units, with each one capable of having up to 30 weapons or sensors, including electronic countermeasures. Typical projects included air-to-air, air-to-ship attack tactics development, force projection/close air support tactics study, conceptual weapons/sensors/platform study, evaluation of tactics developed by pilots at the Naval Strike Warfare Center, NAS Fallon, Nevada, and the Navy/McDonnell Douglas F/A-18. WEPTAC included eight player workstations, a central computer, a conference room, and offices. Simulations forced players to make decisions as they would in actual combat, with the system computing the effectiveness of aircraft, radars, countermeasures, and weapon use. At the conclusion of an engagement, players were debriefed on what actions they took and whether they were successful. [147]

Research, Science, and Technology

Chlorofluorocarbon (CFC) Elimination for Soldering and Fire Suppression Applications
Historically, CFCs were used for cleaning and firefighting applications. They are stable, easy to use, and inexpensive. Approximately 220,000 tons were used worldwide each year, and DOD used it extensively. However CFCs, fell into a category of ozone-depleting compounds. Under President Bush, the U.S. decided to phase CFCs out by 1995. China Lake then evaluated commercially available, non-ozone-depleting products for cleaning electronic assemblies. China Lake helped develop and test low residue no-clean solders, citric-acid-based flux, and wave soldering processes. With military aircraft susceptible to fires caused by ballistic penetration of fuel tanks, Halon 1301 was the agent of choice for extinguishing fires. However, it too was phased out. In response, China Lake developed gas generators ("pyrotechnic extinguishers") that produce large quantities of inert gases to smother fires. The first patent was issued in 1986. [148]

CL-20

Most Significant Energetic Ingredient in 50 Years. CL-20, a breakthrough in energetic materials with higher energy density and lower sensitivity than previous materials, was invented in 1987 by China Lake researchers. CL-20 has been called the "most significant energetic ingredient in 50 years" because of its high performance, minimum signature, and hazard characteristics. The synthesis process for CL-20 was scaled up by industry to produce sufficient material for formulation work, and the formulations have been characterized for performance, signature, and safety properties. CL-20 has important application in the commercial world. A CRADA was established with Thiokol Propulsion to perfect the material for scale-up to commercial production and availability for the military and the commercial applications. (1987) [41]

Data Link

High-speed dual-payout fiber-optic data link was demonstrated. (circa 1988) [46]

High-T Superconductor Antenna

High-performance antenna was demonstrated. (circa 1990) [46]

Injection Loading of Energetic Materials

China Lake began developing injection loading technology in the mid 1980s to meet the Navy's Insensitive Munitions (IM) requirements. This process is a valuable means of loading explosives into munitions, it providing a greater range of loadable viscosities and consistent load quality. For PBXs, injection loading is much faster than conventional casting methods. China Lake built a bench-scale injection loader in 1986 and was certified for live operation in 1995. The injection loader has been in operation ever since. Injection loading is also applicable to the propellant industry. [149]

Natural Pumice Used to Develop Safe Explosive Containers

The Ordnance Evaluation Branch at China Lake was the first branch of the U.S. government to use pumice to protect assets and personnel, resulting in three patents. Explosives engineer Carl Halsey first discovered the useful effects of pumice in the late 1970s while doing sympathetic detonation research. Halsey discovered that pumice, a volcanic ash created as lava cools, is readily found on the China Lake ranges. Pumice contains thin membranes enclosing air-filled cells and is naturally effective at absorbing shock, deflecting blasts, and preventing sympathetic detonation of explosives, reducing explosive chain reactions. The low thermal conductivity of pumice (it melts, rather than burns, at temperatures around 2,500ºF) makes it an ideal fire barrier. At a pumice mine near the Center, natural ash is screened and inserted in its natural state inside of thin container walls. Pumice containers can store more types of explosives in closer quarters, and containers are now used by rapid-response teams in all military branches and by the Fleet for safe packaging, transportation, and storage. Pumice will soon be used in anti-terrorist applications. Pumice is readily available, easy to use, and inexpensive. WD received Congressional funding for continued development in 2002. [150]

Night Marker System

Development of the Night Marker system was completed. (circa 1984) [46]

Radar

New Radar-Warning Device. Interim continuous wave detector (ICWD) radar-warning device was developed during the Iran Crisis. [46]

Refractory Coatings

Durable refractory coatings for diamond surfaces were developed. (circa 1990) [46]

Supersonic Naval Ordnance Research Track (SNORT)

Speed Record. HISS recoverable dual-rail sled for SNORT set a new speed record. (circa 1986) [46]

Thin Films

Scientists discovered a new process for producing specialized thin films. (circa 1988) [46]

Very Large-Scale Integrated (VLSI) Neural Computer

NWC achieved the first known operation of multiplayer, analog, VLSI neural computer with full learning capability. (circa 1987) [46]

Crew Systems

Aircrew Safety

Seawater-Activated Release System (SEAWARS). SEAWARS parachute-release system became operational. (circa 1984) [46]

Space-Shuttle-Booster Recovery System. Testing of the Space-Shuttle-Booster Recovery System was completed. (circa 1984) [46]

Space Shuttle Escape System. The Personal Parachute Assembly was completed for the Space Shuttle Escape System. (circa 1988) [46]

Vertical Seeking Ejection Seat. The vertical-seeking ejection seat concept began at China Lake in the early 1970s. Propulsion control was used to stabilize a seat in the pitch plane only. A moveable underseat rocket motor was used for control. Both static and flight tests were conducted. Early successes quickly led to advanced work on active seat steering and trajectory control. The most aggressive testing was done in June 1978 when an aircraft cockpit seat was suspended from towers in a nearly inverted orientation, 100 feet above ground level (AGL). The seat descended only 43 feet before it had uprighted itself and flew vertically to an altitude of 137 feet. Maximum seat acceleration was 10 *g*s; the on-board dummy experienced 13 *g*s in the vertical direction at the foot

position. This was the world's first successful vertical-seeking ejection-seat demonstration. [151]

Vertical Seeking Ejection Seat. Microwave Attitude Reference System (MARS). China Lake continued to improve the seat with an independent inertial reference system, infrared sensors to define the local horizon, electrostatic sensors, and an array of four microwave radiometric sensors differentiating the "hot" earth from the "cold" sky. This later system, termed MARS, turned out to be ideal because it provided a local vertical reference as well as terrain and obstacle avoidance. Subsequently, MARS was coupled with the vertical-seeking subsystem (VSS) and two additional successful tests were conducted. The final test had the cockpit suspended 100 feet AGL, this time at 135-degree roll angle. During ejection the seat dropped less than 30 feet before reversing direction to a vertical steering trajectory. Dummy/seat separation occurred at 213 feet AGL with the dummy achieving a maximum altitude of 237 feet before parachute deployment, followed by successful recovery. This was the first use of MARS technology in an active control system, the first ejection seat to initialize seat attitude independent of any external systems, and the first use of a self-scaling control law based on local terrain features.

Although the vertical-seeking escape system, in conjunction with MARS, provides the potential to greatly reduce aircrew fatalities and injuries during adverse-attitude and -altitude ejection, the ejection seat has yet to go into operational use. [151]

Special Weapons and Projects

National Aeronautics and Space Administration (NASA)

NASA began testing the parachute system for Galileo Atmospheric Probe. (circa 1980) [46]

VIETNAM CONFLICT (1956-1975)

"Over 75% of the air-to-air and air-to-ground weapons being used in Vietnam were developed at NOTS."
Robert McNamara, Secretary of Defense, 1965

Weapons and Weapon Systems

Air-Launched Low-Volume Ramjet (ALVRJ)

The ALVRJ was a proof-of-concept program to provide a small supersonic propulsion system for a proposed Supersonic Tactical Missile (STM). ALVRJ combined a solid-propellant rocket-booster motor with a ramjet-propulsion system in a single motor case. The ALVRJ used a unique Integral Rocket/Ramjet (IRR) design using the burned-out booster rocket-motor case as the combustion chamber for the ramjet engine. The ramjet sustained the supersonic speed and provided an overall range of about 100 nautical miles. The ALVRJ was a joint effort conducted in the 1960s by China Lake and LTV Aerospace. China Lake was responsible for the design, development, test, and integration of the solid-rocket booster motor and ignition system, as well as releasable port covers and a ejectable rocket nozzle system. LTV contributed efforts on the ramjet propulsion system. Six successful flight tests were conducted at Point Mugu, demonstrating concept feasibility for use in tactical air-launched missiles. The missile was never deployed because the subsonic Tomahawk was selected as the nation's cruise missile. However, ALVRJ technology was used as the primary propulsion system for the Advanced Common Intercept Missile Development (ACIMD). [144]

Antisubmarine Weapons

Antisubmarine Warfare (ASW). ASW was at one time a major area of endeavor for NOTS; the Pasadena Annex was the focus of ASW work, which included technology development, submarine-detection systems, torpedoes, fire control, and delivery systems. China Lake and Pasadena developed a variety of weapons. [46]

Mk 44 ASROC-Launched Torpedo. Introduced. (circa 1958) [46]

Project SWISH. Studies of torpedo hydrodynamic noise were conducted. [46]

Rocket-Assisted Torpedo (RAT). Development completed. [46]

Torpedoes. Mk 32 Mod 2 fielded. Also fielded were the Mk 42/43/44/46. ASW weapons included the Mk 48 torpedo. [46]

Bullpup

AGM-12. The AGM-12 was the first mass-produced air-to-surface command-guided missile developed by the Air Force. The U.S. began to deploy tactical air-to-surface guided missiles as a standard munition in the late 1950s. The first of these was the AGM-12 Bullpup, a rocket-powered weapon that employed visual tracking and radio-transmitted command guidance. The pilot controlled the missile by means of a small side-mounted joystick, and the pilot guided the missile by watching the position of tail-mounted tracking flares in relation to his line-of sight view of the target. Steering commands to correct the flight path were sent through one of the 24 available radio channels. Bullpup was not a China Lake design, but the Station was involved in developing a replacement for Bullpup. The ASM-N-7 Bullpup, first deployed overseas in April 1959, was soon (1960) upgraded to an improved variant, the ASM-N-7A, which was redesignated AGM-12B Bullpup-A in 1962. The Bullpup B entered USAF service in 1965 and was carried by F-4 and F-105 fighters during Vietnam. Its small warhead, however, was inadequate against North Vietnamese bridges. The Navy's Walleye proved much better. The AGM-12C Bullpup B was a larger follow-on version of the original Bullpup air-to-surface radio-guided missile. The AGM-12C carried a 1,000-pound semi-armor-piercing warhead in the enlarged midsection. [144]

Bulldog

AGM-83. The Bulldog, which followed Bullpup, was a short-range, air-launched, laser-guided weapon that used a solid propellant and a high-explosive warhead. It was the first successful laser-guided missile. The AGM-83 was conceived, designed, and developed by China Lake as a replacement weapon for the AGM-12 Bullpup that was used considerably in Vietnam but had several operational problems. The new Bulldog solved the problem of using liquid fuel aboard aircraft carriers, reduced the vulnerability of the launch platform to ground fire during weapon delivery and improved

performance against hard targets. The Bulldog laser-guided missile corrected many of the earlier Bullpup problems and was approved for service use in 1974; however, manufacture and deployment were cancelled in favor of the Air Force Maverick. [144]

BROK

Atomic Bomb Case Mk 12. The Mk 12 Atomic Bomb (nicknamed BROK) was designed for high-speed delivery from fighter/bomber aircraft. The Mk 12, first manufactured in 1954, was produced through 1957. The weapon was retired from inventory in 1958. China Lake/NOTS designed the Mk 12 bomb case for high-speed carry on tactical aircraft. [144]

Condor

AGM-53. The AGM-53 Condor effort was to develop a long-range air-to-surface missile for attacking high-value and strategic targets from naval aircraft without the need to penetrate heavily defended enemy airspace. The basic Condor was rocket propelled and used a small TV camera located in the nose of the missile for targeting and tracking. The missile had an average range of 10 to 20 miles, depending on launch altitude. It used a data pod on the launch aircraft for midcourse navigation and terminal target lock-on. Basic Condor was followed by two major improvements. First, the TV guidance was replaced with a dual-mode seeker consisting of a radar and a small TV camera to improve capability in all-weather conditions. Second, the solid-rocket motor was replaced by a turbo-jet engine to provide extended-range capability. China Lake was the lead field activity and technical manager responsible for initial development. China Lake also provided the technical direction for the dual-mode seeker and turbojet design. China Lake provided technical direction for the prime contractor in the areas of systems engineering, guidance, fuzing, warhead development, system safety, propulsion, aircraft interface and cost analysis. Flight demonstrations were also conducted. Condor completed development, testing, pilot production, and long lead production; however, the program was later canceled by Congress. [144]

Eye Series

The Eye series of weapons was extensively used in combat. The Eye weapons program included development of cluster weapons-canisters containing numerous bomblets that, after aircraft release and splitting of the canister, scatter during free fall to earth, resulting in explosive effects over a considerable area. The Eye series of free-fall weapons (originally targeted with an "iron bombsite and a Mk 1 eyeball") began in the late 1950s with a China Lake study that showed the need for improved conventional weapons. [46]

Antipersonnel/Antimateriel Cluster Weapon (APAM)

A later China Lake evolution of Rockeye was named APAM. APAM uses the Rockeye canister but has many more, and more versatile, bomblets as its payload. [46]

Briteye. Balloon-borne flare. [46]

Deneye. Antitank mine-dispenser system. [46]

Fireye. Gelled-fuel weapon. [46]

Gladeye. Multi-option modular dispenser weapon released to the Bureau of Weapons (not fielded). (circa 1963) [46]

Mk 20. The basis for other dispenser weapons, such as the current Gator mine-delivery system. [46]

Padeye. Cluster weapon completed but not produced. (circa 1968) [46]

Snakeye. Fin retarded bomb (Mk 81/82 GP bombs). 250- and 500-pound bombs released to the Fleet. (circa 1963) [46]

Sadeye. Cluster bomb dispenser. Completed but not fielded. (circa 1963) [46]

Rockeye II. Introduced to the Fleet and later used in combat. Extensively used in Southeast Asia, was conceived as an antitank weapon. Although not many tanks were in that conflict, the weapon was highly effective against targets such as truck convoys, radar sites, and parked aircraft. (circa 1962) [46]

Encrypted Telemetry

In the late 1970s, a telemetry system was designed for Sidewinder AIM-9L using a pulse code modulation format to demonstrate the feasibility of using standard National Security Agency miniature encryption devices to protect missile-performance information during airborne testing of weapon systems. The test was successful, resulting in the capture and display of all transmitted performance information. The Secretary of Defense soon mandated the use of encryption on DOD tests to protect the information from compromise. Since the mid 1980s, most of the weapons telemetry systems have used encryption. The first aircraft to use encryption was the F/A-18 in 1991. [154]

5- and 8-Inch Guided Projectile Programs

The Guided Projectile was a fin-stabilized round, fired from 5-inch, 54-caliber Navy guns, using in-flight rocket propulsion, canard aerodynamic steering control, and either a semi-active laser or passive IR seeker for terminal homing against ship defense targets. In 1972 China Lake developed a rocket motor assembly that could withstand up to 8000 *g*s of axial acceleration, a set of delayed-opening trailing folding fins for round stability, a slip obturator to seal high-pressure gun gasses behind the projectile, and a gun-gas pressure-initiated rocket-motor igniter. Three motor configurations were designed and tested, and all used high-strength propellants. China Lake evolved a very high-performance end-burning design that operated at higher than normal chamber pressures. The folding-fin assembly survived the dynamic gun environment, and unique new fixtures allowed the fins to hold alignment. The slip obturator sealed the 40,000-psi gun pressures while reducing muzzle spin rates to less than

20 rev/s. The gun gas-actuated igniter featured a built-in pyrotechnic ignition delay to ensure safe and reproducible gun separation before initiation. China Lake conducted many five-inch-gun flight tests in addition to air drops of the first powered rounds. In all, China Lake built more than 400 rocket motors before delivering the documentation package for transition to industry. China Lake also developed an eight-inch guided projectile that used a forward-folding-fin assembly. After fin deployment, the rocket motor's multiple nozzles exhausted between the fins. The eight-inch round and rocket motor were successfully tested in launches from the M110 self-propelled howitzer and the Navy's eight-inch bag gun. [151]

Fuel-Air Explosive (FAE) Weapons

China Lake developed and applied the FAE technology. From grenades up to 2,000-pound FAEII bombs (BLU-96/B). [46]

Land and Mine Clearing. China Lake developed FAE weapons that were successfully used in Vietnam and became part of the operational arsenal of the Navy and Marine Corps. FAE weapons rapidly cleared landing zones and minefields and neutralized field fortifications. Potential nonmilitary applications include brush clearing for reforestation products. [155]

FAE-1 (CBU-55/72). FAE-1 (CBU-55/72) was deployed in 1970; further developments have included surface-launched mine-clearing systems (surface launched unit (SLU)-FAE and catapult-launched FAE (CAT-FAE)). This was the first FAE weapon used in combat. In 1972 improved FAEs entered combat service. [46]

Fuzing Systems

First Active-Optical Fuzes. China Lake developed the first active-optical fuzes using solid-state lasers—the DSU-10 for the Standard ARM (developed in 90 days during 1968 to meet a Vietnam War requirement), the DSU-15 for Sidewinder, and the DSU-19 for HARM. The Center developed the China Lake universal rocket motor arming-firing device (AFD) to prevent accidents such as the 1967 disaster aboard *USS Forrestal*. This single device replaces a vast proliferation of rocket motor AFDs that were in the Fleet until the 1970s and offers significant improvements in safety and reliability. (1968) [141]

Guidance and Control

Experimental Navigation Model. China Lake tested in Advanced Tactical Inertial Guidance System (ATIGS). (circa 1974) [46]

Mighty Mouse

Most Fired Non-Bullet Item. The 2.75-inch Mighty Mouse saw its heyday in Southeast Asia, where it became the most fired non-bullet ordnance item in combat. [46]

Prime Strike Weapon. Mighty Mouse is one of the China Lake's major contributions to defense and was used by the Army, Navy, Air Force, and Marine Corps. It was used extensively in Korea and Vietnam in antipersonnel, antimateriel, and flak-suppression strikes. The Army, using the slow-roll modification developed by China Lake, made Mighty Mouse one of its prime strike weapons. It became, and continues to be, a principal helicopter weapon in all services. [145]

Polaris

Major Role in Rocket Motor/Underwater Launch Testing. One of China Lake's most significant areas of accomplishment is in Fleet ballistic missile support, especially Polaris. Early development began in 1958. The Polaris studies conducted by China Lake were instrumental in developing the Polaris concept and weapon system. China Lake played a major role in rocket motor testing and underwater launch testing. The T&E role continued to be significant, as witnessed by the huge Trident II motor test facilities that opened in 1986. (circa 1958 - 1999) [167]

Propulsion Systems

Hybrid Propulsion System. First successful U.S. flight test of a hybrid propulsion system. (circa 1961) [46]

QuickTurn Thrust Vector Control (TVC) Flight Vehicle

The QuickTurn TVC flight vehicle was demonstrated and developed into the Agile missile. Agile was the forerunner to the Sidewinder AIM-9R and AIM-9X missiles. (circa 1969) [46]

Agile XAIM-95 Experimental Air Intercept Missile

Agile was an advanced development proof-of-concept effort to design a short-range air-to-air missile to fill the gap in air-combat effectiveness between aircraft guns and longer-range air-to-air missiles. China Lake introduced a number of advanced-technology firsts for missile design. A three-gimbal IR seeker provided a large off-boresight acquisition and launch capability. Missile propulsion and maneuverability was provided by the first tactical-sized (eight-inch-diameter) integrated thrust-vector-controlled rocket nozzle. A new active-optical fuzing system, which pulsed light waves, was used for target detection. In addition, a double-end initiated-focused fragmentation warhead concentrated fragments in a dense ring around the missile. The airframe was a wingless design, incorporating a free-to-rotate tail assembly that removed the effects of induced roll. China Lake also pioneered a helmet-mounted targeting system that permitted the pilot to acquire the target simply by looking at it. China Lake was the lead development laboratory for the advanced development effort for Agile. Working with various contractors, China Lake developed and tested all of the major subsystems, including the seeker, the propulsion/guidance system, target sensing and fuzing device, warhead, airframe, thrust-vector-control system, and the fire-control system. The missile was never put into service; however, each of the major subsystems was separately introduced into the Fleet in other weapon systems. [144]

Shrike

China Lake "Wrote The Book" on Antiradiation Weaponry. China Lake's involvement, starting with early paper studies in the 1950s, was actually the Navy's initial involvement. China Lake, working with Sperry and Texas Instruments, evolved Shrike, a production antiradiation weapon that was released to the Fleet in 1966, although some preproduction models were taken to Vietnam in February 1965. In Vietnam, the weapon was used in a tactical war of attrition, and an array of variants had to be developed expeditiously to cover the enemy radar spectrum. Shrike has been out of production since 1981 but continues to be a highly important element of the operational U.S. ARM weapons arsenal. [141]

Shrike (AGM-45). Most-Fired Guided Missile. Shrike is another China Lake development demanded directly by the Fleet. The first successful antiradar missile, Shrike has become one of the most-fired guided missiles in history since its 1965 combat debut. Along with Shrike developments, China Lake antiradar technology programs (e.g., ERASE and its products and by-products, such as the antiradiation projectile (ARP)) provided the foundations for the next generation of antiradar missiles, including HARM (AGM-88). [145]

Shrike-On-Board (SOB) and Sea Chaparral. Shrike-On-Board and Sea Chaparral were developed in quick-reaction efforts for shipboard combat use. (circa 1972) [145]

Shrike-On-Board (SOB). The SOB system was another quick-response effort to adapt the Shrike to shipboard launch for purposes of destroying or deterring North Vietnamese coast-defense radars. The SOB system was used effectively in combat 104 days after the initiation of the program. [141]

Sidewinder 1950s

Sidewinder 1A. First Guided Missile Ever Used Successfully in Air-to-Air Combat. China Lake developed the Sidewinder missile, the world's most successful dog-fight missile. The Chinese Nationalists used the Sidewinder 1A in combat in September 1958, and it has been said that the availability of the Sidewinder may have been a critical factor in heading off an invasion of Taiwan at that time. Wally Schirra, the pilot who fired the first all-up Sidewinder missile, was then stationed at China Lake and was destined to achieve fame as an astronaut. Sidewinder is certainly China Lake's best-known success, although far from being its only one. Sidewinder was developed by China Lake beginning with a 1949 feasibility study that begat the "heat-homing rocket," which became Sidewinder. Fielded in 1956 and combat proven in 1958, AIM-9A through AIM-9M versions of the deadly little heat-seeker have served the Fleet for more than 35 years. Developed and modernized with the principles of simplicity, reliability, and producibility in mind, the AIM-9M family of missiles has proven to be the world's most accurate, reliable, and successful dog-fight missile—a missile adopted and copied by friend and foe alike. (1958 - present) [156]

Used by More Free World Powers Than Any Other Missile. By the time of the Vietnam War, China Lake had evolved the Sidewinder into a solid-state version with a variety of other improvements. Sidewinder had become "the" air-to-air missile, with most Free World powers using it. The Soviet Union was employing a literal copy of it as well. The missile accounted for most of the air-to-air kills in the Vietnam War. Sidewinder's low cost and high reliability were becoming a legend in the Fleet. (circa 1956) [141]

Sidewinder 1960s

AIM-9C and -9D. Semiactive radar-homing (AIM-9C) and advanced IR homing (AIM-9D) versions released to the Fleet (circa 1963) [46]

Chaparral. Army Chaparral SAM (modified Sidewinder) was fielded. (circa 1968) [46]

Sidewinder 1970s

Agile. During the 1970s NWC pursued Agile (XAIM-95), an advanced dogfight missile combining China Lake technology advancements in TVC, guidance, and targeting. Much of this technology is the basis for the AIM-9X Sidewinder design. [46]

Targeting

Targets. Countering Vietnam Threats. By the late 1960s, targets and threat simulation at Point Mugu had reached new levels. A QT-33A, a full-size aerial target, provided a cost-effective, comprehensive simulation of the threats the Fleet was encountering in Vietnam and helped engineers develop and test improved conventional weapons and EW systems. [157]

Decoys. Countering Vietnam Threats. Late in the war the North Vietnamese were able to import a new antiaircraft missile system that was highly effective. An urgent need to find ways of countering the system was expressed in the form of a phone call from the Marine commander in Vietnam to the associate technical director at China Lake. The Center carried out field tests of available equipment and feasible tactics the same day the call was received and provided recommendations by message traffic that night. That effort, plus the rapid development and deployment of a new decoy device, is believed to have saved numerous aircrews and aircraft. [141]

Laser Target Designator—Pave Knife. Pave Knife was an Air Force laser target designator (a pod). China Lake became a quick-reaction program during the Vietnam War to adapt the designator to the Navy's A-6 aircraft. The designator was used as an interim system pending completion of the A-6E TRAM system. This was an extremely successful venture, completed on time and deployed expeditiously. Pave Knife was one of the most potent weapon systems in the Vietnam Conflict. VA-145 destroyed 14 North Vietnamese bridges in three hours. [141]

QF-86H Full-Scale Aerial Target (FSAT). Program completed. (circa 1975) [46]

Walleye

First TV-Guided Glide Bomb. The Walleye (AGM-62) TV-guided glide bomb, was designed and developed by China Lake and was the first precision-guided antisurface weapon. An outgrowth of in-house technology efforts, Walleye was fielded in 1967 and proved its unsurpassed accuracy in combat. Walleye II was released to the Fleet circa 1972. Extended Range Data Link (ERDL) Walleye II was released circa 1974. [145]

Weapon-Release Computer

CP-741/A Weapon-Release Computer. The CP-741/A computer was installed in the first Fleet aircraft. (circa 1966) [46]

Zuni

Heavily Used. China Lake's five-inch Zuni rocket was heavily used over the years. China Lake was the lead laboratory for the 2.75 and Zuni developments. The Zuni, as well as some other early unguided rockets, was originally conceived as an air-to-air weapon, but the rocket's role evolved into that of an air-to-ground weapon. Interestingly, the Zuni shot down a MiG-15 early in the Vietnam War when the MiG let itself get ahead of an A1 Skyraider that was trying to evade it. The Skyraider fired a Zuni and scored a hit. [141]

Test and Evaluation/Range Support

Aircraft Targets

By the late 1960s, target and threat simulation work at Point Mugu was in full force. Aerial targets ranged from simple tow targets and banners to high-altitude supersonic missile targets, and from small expendable subsonic targets to full-size aircraft. Surface targets ranged from high-speed patrol boat simulations to full-size decommissioned warships. **Missile Targets** included the XBQM-34E, which operated at between 50 and 60,000 feet and evaluated the performance of autopilots. The MQM-74A was designed to simulate a medium performance aircraft and could fly up to 500 knots at altitudes up to 40,000 feet. The Bomarc, CQM-10A, allowed the user to test both high- and intermediate-altitude surface-to-surface missiles. **Aircraft Targets** included the full-size, high-*g* QT-33A and the QF-4B, which came aboard in the 1970s. The low-altitude AQM-37A targets were designed to simulate low-altitude threats, such as cruise missiles. **Surface Targets** in the early 1970s included SEPTAR Mk 33/Mk 35 boat targets and were deployed to Pearl Harbor and Puerto Rico. **Ship Targets** were developed in the 1970s ship targets as a result of the Harpoon test program. These *Fletcher*-class destroyers were designated long-term targets, and several sustained as many as 13 direct hits by inert missiles. **Land Targets** were also developed, including the QM-56 (gun carriage) and QM-41 (tank). Targets could be radio-controlled for use on the bombing ranges. [50]

Bomarc

Simulated MiG Performance at Mach 2.65. Point Mugu established a special target division to launch target versions of the Air Force's Bomarc surface-to-air-missile. Bomarc simulated the performance of the Soviet MiG-25, reaching a speed of Mach 2.65 at an altitude of 65,000 feet in the 1970s. (circa 1970) [136]

Electronic Combat Range (ECR)

ECR Saved Lives. If the ECR, or "Echo Range," at China Lake had not become operational when it did (1968), the U.S. would almost certainly have lost many more pilots in Vietnam than it did. A combination of EW "gadget" development, tactics development, evolution of tactical doctrine, and Fleet training in EW operations, all made possible by Echo Range, was of exceptional importance in the air war in Vietnam. [141]

Fast Cookoff Testing

During the 1960s, the U.S. Navy experienced major aircraft-carrier disasters aboard *USS Oriskany*, *Forrestal*, and *Enterprise*—all caused by ordnance burning and detonating from the heat of deck fires. Hundreds of Sailors died, and scores of aircraft were destroyed or damaged. China Lake engineers responded, devising a method for exposing ordnance to a simulated carrier fire to determine how much time the crew would have to react. This procedure, known as fast-cookoff testing, involved collecting data using thermocouples and time-to-reaction instrumentation. Later, attempts were made to test materials that would stretch the time between the onset of the fire and a violent reaction. However, the sophisticated technology necessary to understand the reaction of the ordnance did not yet exist. China Lake had been using real-time x-ray technology for years to test rocket motors, and engineers wanted to use this same technology to investigate the reaction of a rocket motor in a pool of fire. When China Lake developed a high-energy real-time x-ray system, such tests became possible. Test engineers still had to design special hardware and use unique applications of currently available materials to fit the extraordinary test environment. The most notable challenges were a high-flux 2000°F pool fire, blast from a rocket-motor exhaust plume, and blast and fragmentation from a rocket motor blow-up. These had to be dealt with while simultaneously acquiring real-time x-ray data of sufficient quality to diagnose the reaction of the rocket motor. A dramatic 2000-pound bomb test was later conducted and these highly successful tests resulted in a full understanding of why and how rocket motors reacted. As a result, rocket motors were redesigned to allow more time before any would react to a fire. [158]

5,000-Mile "Shooting Gallery"

By 1960 instrumentation had been installed at 17 sites on the Pacific Coast, including Point Mugu, Point Arguello (Vandenberg), San Nicolas Island, and the far islands of Hawaii, Eniwetok, Midway, and Wake. Mobile instrumentation and recovery capability was also acquired. This included a fleet of heavily instrumented range ships

(mostly converted WWII Victory ships) and aircraft (C131 Constellations), all needed to cover the broad Pacific area that had become a 5,000-mile "shooting gallery." At its peak in 1963, the Pacific Missile Range had more than 13,000 military, civilian, and contractor personnel on board, commanded by a rear admiral, with deputy commanders from the Army, Air Force, and Navy, and representatives from the Marines, NASA and the AEC. [153]

Hydra

Project Hydra studied the comparative methods for launching satellite, high-altitude probe, and rocket vehicles at sea. Hydra using a floating launch technique. A rocket vehicle was floated in a vertical position with its nose slightly above the waterline; when fired, the rocket exhausted its gasses directly into the water, with the ocean acting as the launch pad. One unique test vehicle consisted of an 11,000-pound, 105-foot-long telephone pole that was sea-launched. In addition, model tests were conducted in the wave motion tank at Port Hueneme, to study whether various rocket designs could maintain vertical launch attitude. Another test involved a 37,000 pound unguided probe vehicle, the Hydra IV. In the 1960s the first full-term, multi-stage launch vehicle, the Hydra-Iris, was developed. It could loft a 100-pound payload to an altitude of 175 nautical miles when launched from a floating rail launcher. Point Mugu designed the booster assembly containing three Sparrow motors and the common ignition system. The Hydra-Iris launch vehicles carried x-ray astronomy payloads designed and built by the Lawrence Livermore Radiation Laboratory. By June 1968, eight successful launches had been made. The idea of sea-launched ICBMs was reconsidered in the 1980s as a possible alternative to MX horizontal shelter basing. [50]

Nike-Zeus

500,000-Pound Thrust. Nike-Zeus, the Army's early antiballistic missile, was not evaluated by Point Mugu but was launched from Point Mugu, making use of the their instrumentation. Between 1960 and 1962, 19 Nike-Zeus missiles were fired from the Point Mugu beach area. The first-stage booster of almost one-half million-pounds thrust was the most powerful rocket ever fired at Point Mugu. Each test set desks and cabinets rattling. [136]

Photo-Optical Instrumentation

A milestone event in photo-optical instrumentation occurred at Point Mugu in 1965 with the design and development of the AFH-14 supersonic aircraft camera pod. The pod, attached on the centerline of the photo chase airplane, had one forward-looking camera station and multiple side-looking stations. It could carry a 70mm sequential camera, 35mm and 16mm high-speed instrumentation cameras, and a TV camera. The camera pod found extensive use in photographic surveillance of aircraft, missile launches, flights, and intercepts. [50]

Mobile Optical Tracking Unit (MOTU). Optical data were obtained with the MOTU developed by Point Mugu engineers. This two-man tracking unit used servos attached to drive belts to operate the instrument in azimuth and elevation. Seventy-millimeter cameras were used on the mount with various short- or long-focal-length lenses. For recording surface-launched missiles during first motion, remote control Bowen-type cameras were installed on both sides of the launcher. Started just prior to ignition, they provided a continuous record of lift off. [50]

Point Mugu Programs

Point Mugu and their tenant activities have tested and evaluated hundreds of missiles, weapon systems, and vessels for all branches of the military as well as for NASA and private industry. A few programs prior to 1990 included: AEGIS/Standard Arm, Aerobee, ALVRJ, AMRAAM, ASROC, Athena, Atlas, Bat, Blue Straw, Bullpup, Cleansweep, Condor, Corvus, Crow, DYNA-SOAR, Eagle, Gar-9, Gargoyle, Gorgon, HAD, HARM, Harpoon, Hawk, Hellfire, Hihoe, Hugo, Hydra, Jane, Javelin, Lark, Laser Guided Bombs, Little Joe, Loon, Marquardt Hyperjet, Maverick, Meteor, Minuteman, Mk 94/Pegasus, NERV, Nike-Zeus, Niteowl, Oriole, Pacer Kite, Penguin, Petrel, Phalanx, Phoenix, Polaris, Press, RAM, Rare, Regulus, Rigel, Safeguard, Sail, SARV, Sidewinder, Sidewinder ARCAS, Shrike, Sidearm, Skip, Skol, SLAM, Sparoair, Sparrow, SeaSparrow, Standard ARM, Standard Missile, Talos, Tartar, Teepee, Terrier, Thor, Thor/Agena, Terrasca, Titan I and II, Tomahawk, Tow, Transit, Trident, Tumbleweed, Vista, and Walleye. [50]

Physiological Research

For many years, Point Mugu supported the Fleet by developing techniques for obtaining in-flight physiological data, especially in the multi-stress environment of flying tactical jets. In the late 1950s, research was conducted to design and build an instrument that would monitor and record in-flight aircrew electrocardiogram, respiration, and pulse rates. In the late 1960s, the Navy developed an in-flight recorder Bio-Pack for monitoring such functions. This device transitioned to the In-Flight Physiologic Data Acquisition System (IFPDAS), used at Point Mugu to monitor aircrew flying the A-4, F-4, and F-14 aircraft. By the late 1970s Point Mugu engineers had made further advancements to the IFPDAS III. This knowledge was used to develop specifications for future life support systems. [50]

Real-Time Radioscopy (X-Ray Video) of Rocket Motors Firing

China Lake is a pioneer in rocket-motor radioscopy (x-ray technology), developed in the 1960s. The system took clear images of high-risk rocket motor failures and malfunctions. This x-ray capability allowed internal-component behavior to be observed during static firing, allowing engineers to better understand such things as slag, bond issues, and burn rates. With this new tool, engineers began designing methods to improve reliability and performance. It was the only system of its kind in the free world, and it made China Lake one of the premiere places to test solid-propellant rocket motors. By the mid-1980s, engineers had developed a workable high-energy

real-time radioscopy (RTR) capability built around a nine-million-electron-volt linear accelerator. The multi-million-dollar invention, which included a 12,000-pound accelerator assembly and image system, was first used on a first-stage Trident rocket motor and later used in the nozzle-down firing of a small Intercontinental Ballistic Missile booster motor to provide real-time slag-behavior data for the Air Force and Thiokol Corporation. A series of Minuteman first-stage motors were also tested. Perhaps the most ambitious and difficult imaging task came in 1993, when Thiokol asked China Lake to help solve a Space Shuttle booster motor problem, which if not solved could ground the shuttle. Unexplained pressure perturbations were creating flight-safety concerns. China Lake performed three on-site, real-time tests that clearly identified a slag-ejection problem. Through the years, RTR testing has benefited NASA, industry, and all branches of the military. Many papers, publications, and talks—national and international—have described the system capability. This technology earned a prestigious award (R&D 100 Award) for the scintillating glass that improved x-ray imaging and found considerable use at Lawrence Livermore and Los Alamos laboratories. A low-light-level, high-frame-rate video system went on to be further developed by Kodak. China Lake continues to use RTR to better understand rocket-motor internal-component behavior during all life-cycle stages of a motor, from development to production-item testing. [158]

Telemetry

In 1964, Point Mugu acquired the TAA-2 85-foot parabolic dish antenna. It was first modified to receive the satellite television signals of the Olympics held in Japan, and then reconfigured to track experimental satellites, including those involving the "monkey in space" program. In 1967, auto tracking 30-foot parabolic dish antennaes were installed that used an ultra-high-frequency (UHF) regime. Point Mugu was the first national or service range to fully convert to the new system. [50]

Energetics

Insensitive Munitions

In 1967, on the deck of *USS Forrestal*, a Zuni rocket was accidentally fired into an aircraft, starting a fuel fire. The fire and exploding ordnance took the lives of 134 Sailors and destroyed 21 aircraft. Deadly fires involving ordnance have also occurred aboard the carriers *Oriskany*, *Enterprise*, and *Nimitz*. These disasters spurred the Navy to investigate insensitive munitions (IM)—rocket motors and warheads that will fire or detonate only when intended and not as a result of unplanned stimuli. In the early 1970s when the Navy Fast Cookoff Improvement Program began, the intent was to delay ordnance reactions so the bombs would not detonate as quickly when exposed to fires. This work progressed, making the reactions less violent. The Ordnance Hazard Evaluation Board was formed in 1984 at China Lake to review the fast cookoff tests and to present a single, balanced position to Washington, D.C. Since then, China Lake has become a leader in IM research, development, and testing. Scientists and engineers have developed new insensitive energetic materials, loading techniques, warhead and motor case designs, and shipping containers. China Lake also developed the FRAGMAP engineering code and SMERF hydrocode, which are used to analyze sympathetic detonation and to determine size-barrier requirements. Specialized IM test facilities at China Lake evaluate weapons with explosive weights from 20,000 to 200,000 pounds of Class 1.3 explosives. X-ray or high-energy computed-tomography inspection can be conducted before test to document the weapon's condition. WD's IM contributions include improvements to HARM, SLAM, AMRAAM, JSOW, Tomahawk, Penguin, Harpoon, GBU-24, and BLU-110 and -111 general-purpose bombs. WD provides IM services to joint service customers as well as to foreign and international programs. [40]

Reduced-Smoke Propellant

China Lake developed reduced-smoke propellants for tactical weapons and was the first to static fire and flight test full-sized rocket motors containing the solid propellant. At the end of WWII, solid rocket motors were made from the same double-base (smokeless powder) propellant that was used in guns, and propellants used a combination of nitroglycerine and nitrocellulose. Most modern rockets use composite propellants that are rubber binders filled with powdered ammonium perchlorate (AP) and other solids, such as powdered aluminum. Cast composite propellants deliver much higher performance than previous propellants and can be cast into motors of any size and shape. AP provides the oxygen that burns the rubber binder and the powdered aluminum; however, powdered aluminum also creates a dense, white-smoke trail that is not desirable because it alerts the enemy. So, in the 1960s, the HARM and Sidewinder programs required rocket motors containing smokeless propellants, and China Lake engineers developed a composite propellant without the aluminum powder. This became known as reduced-smoke propellant. Removing the aluminum caused only a slight reduction in performance, but it did introduce the problem of combustion instability. China Lake soon solved these problems and became widely recognized in this field. In the 1970s, reduced-smoke motors for HARM and Sidewinder were introduced into the Fleet and later were used in many other air- and surface-launched missile systems. [159]

Roseville Benson Investigations

The extraordinary technical expertise of China Lake's scientists and engineers has had unusual applications. In 1973 explosions rocked two trains carrying Air Force bombs filled with Navy-developed explosives. The incidents, at Roseville, California, and Benson, Arizona, shook public confidence in the safety of military ordnance and resulted in huge damage suits against the government. China Lake explosives experts conducted a rigorous examination of the entire process of the design, manufacture, and quality control for the Mk 81 and Mk 82 bombs involved and solidly demonstrated the safety of

the weapons. Through careful scientific investigation of the explosion sites and laboratory analysis of the evidence, the China Lake team isolated the cause of the disasters to faulty brake shoes that set fire to the wooden boxcars carrying the bombs. Over a period of seven years, China Lake scientists and engineers assisted U.S. attorneys in developing the technical aspects of a defense that saved the government between $50 and $90 million in damages. [40]

Survivability/Vulnerability/Lethality

Joint Technical Coordinating Group for Munitions Effectiveness (JTCG/ME)

The JTCG/ME was established in 1964 to ensure standardization of weapons-effectiveness data among the services. China Lake participated extensively in the planning stages of the JTCG/ME and has maintained a strong influence in the group up through the present time. The manuals produced by this group are the only approved sources of data and methodology for determining weapon requirements for given strike packages. All the weaponeering done in Vietnam, Kosovo, Desert Storm, and Iraqi Freedom was accomplished using Joint Munitions Effectiveness Manuals (JMEMs) produced by the JTCG/ME. The methodology at the core of the Air Force and Navy programs used to determine weapon inventory levels was developed by the JTCG/ME. China Lake scientists and engineers have chaired or co-chaired almost every group in the JTCG/ME organization, including JMEM Anti-Air, JMEM Air-to-Surface, Tomahawk Working Group, Delivery Accuracy Working Group, Small Computer Methods, Target Vulnerability Group, Systems Characteristics Working Group, and the Soviet Ship Vulnerability Program. [160]

Modeling and Simulation

Environmental Simulation

During the 1960s, environmental simulation facilities were developed. The most common variables were temperature, altitude, acceleration, vibration, salt fog, humidity, and shock. Environmental chambers were installed that could send the temperature to a frigid 100 degrees below zero or up to a searing 1,000 degrees. Altitudes ranging from sea level to 300 miles could be simulated and accelerations up to 1,000 *g*s could be produced. Point Mugu constructed a large sea level environmental chamber where missiles and weapons were exposed to rain, snow, sleet, heat, and cold, but the entire fighter aircraft could be subjected to these elements while ordnance personnel loaded the weapons using the actual ground support equipment. These facilities were used until the mid 1990s. [50]

Research, Science, and Technology

Chemiluminescent Light Stick

Now a Worldwide Industry. Light stick technology was developed by China Lake researchers between 1962 and 1986 for the military use as emergency lighting for life rafts, downed flyer beacons, map reading, and damage evaluation. An improved technology was patented in 1986 and 1987 and licensed commercially. Commercial uses include novelty items and safety illumination sticks for emergency kits, commercial fishing lures, and high visibility, brightly glowing, novelty safety necklaces. This technology received the 1993 FLC Award for Technology Transfer Excellence. (circa 1962 - present) [130]

Explosive Forming and Welding

During the 1960s, two of NAVAIR China Lake's most renowned scientists, John Pearson and Dr. John Rinehart, were the inventors of explosive forming and explosive welding—two exotic techniques that revolutionized metal fabrication. In the course of their investigations into terminal ballistics, shaped charges, and metal-explosive systems at the Naval Ordnance Test Station, the two men discovered that a small explosive charge is capable of exerting tremendous forces on a piece of metal by generating shock waves through a medium (usually water or oil), which can then be directed to deform a workpiece at very high velocities. In a second method, an explosive charge is held in direct contact with the workpiece while the detonation is initiated, producing interface pressures on the surface of the metal up to several million pounds per square inch. The shock waves perform the same function as a mechanical punch. These explosive forming techniques reduce the cost of the production (since die alignment is avoided), have high accuracy, and are useful for forming metal sheet and tubular parts; complex shapes such as double curved surfaces; and large, thick parts. Explosive welding bonds two surfaces in a solid state by creating a jet of metal in front of the detonation front. Once employed mainly to clad large areas of one metal with another, the technique is now used to produce corrosion resistant pressure vessels, transition joints for shipbuilding, electrical busbars, and heat exchangers for nuclear installations. Pearson authored *The Behavior of Metals Under Impulsive Loads*, and, with Dr. Rinehart, *Explosive Working of Metals*, two books that are still classics in their field. Today, the techniques pioneered by Pearson and Rinehart are widely used in the aerospace and aircraft industries and in the production of automotive components. [40]

Federal Laboratory Consortium (FLC)

China Lake Helps Establish. The FLC is the national technology transfer organization for federal laboratories. Today, more than 700 major federal laboratories and centers and their parent departments and agencies are FLC members. China Lake was an early advocate for participation by the Federal laboratories in technology-transfer activities with the private sector. The precursor to the FLC was established by China Lake in 1971 as the DOD Laboratory Consortium for

Technology Transfer, which grew from 11 original member laboratories in 1971 to 200 laboratories in 1975 under China Lake leadership. It became the FLC in 1974 and was chartered by the U.S. Congress in 1986.

China Lake was instrumental in initiating and sustaining a movement that resulted in subsequent technology transfer legislation and a strong and committed technology-transfer program within the Federal laboratory system. (circa 1971 - 1975) [130]

Forward-Looking Infrared (FLIR)

First Real-Time IR Night Display of Targets. Beginning with independent and exploratory development work in 1962, China Lake developed the technology and hardware to provide the Fleet with an effective night-attack capability using FLIR devices. An early success was the Advanced Development Attack Model (ADAM) search set and ADAM FLIR display, which demonstrated the first real-time IR night display of targets. This early development work led to the night-attack systems now operational on naval aircraft. (1962) [156]

Geothermal Energy

World-Class Resource Ranking Among the Top 10 in Total Power Output. In 1964, geological engineers at China Lake discovered the enormous geothermal potential on the northwest portion of the base. In 1977 a Navy plan was developed for a private industry contract. The intent was to take advantage of the geothermal energy to generate savings to the Navy for the cost of electricity and to stimulate the Navy's alternate energy program, allowing the Navy to become more independent of foreign fuels. A contract was awarded to California Energy Company, Inc., in December 1979 to produce 75 megawatts at no capital cost to the federal government except for local administration costs. The contract was later modified to accommodate greater production in 1984. The peak output is 263 milliwatts, of which approximately 182 is from Navy land and 81 is from Bureau of Land Management leases. The project is forecast to produce power at least through the primary term of the contract (2009) and likely will continue at near full capacity for another 10 years beyond that. The Coso Geothermal Project is a world-class resource, ranking among the top 10 in total power output. NAWS receives a reduction in their electricity bill every month, a situation that has been in place since first power was generated in 1987. Total savings to NAWS since that time is on the order of $36 million. The Navy will save in excess of $500 million during the life of the contract. It would take more than 240 million barrels of oil to produce an amount of electricity comparable to that which the Coso Project will produce over its 30-year lifetime. China Lake was assigned the lead role for all Navy geothermal effort, not geographically limited to China Lake. (circa 1964 - present) [141]

Jet Vane Thrust Vector Control (TVC) System

The TVC system for Vertical-Launch Sparrow was completed and tested. (circa 1974) [46]

Logarithmic Amplifiers

Joint Work with Mayo Clinic. The first ultrasonic body scanner was pioneered at China Lake during the late 1960s and early 1970s. Logarithmic amplifiers are nonlinear amplifiers that compress and limit the amplitude of large dynamic range electronic signals. At China Lake, these amplifiers were under development for radar signal processing applications. Sonar signals can also have very large dynamic ranges. In 1971, a China Lake radar design engineer transferred the design for a custom logarithmic amplifier to the Mayo Clinic, which was instrumental in the design, development, and successful demonstration of the first ultrasonic body-scanning equipment. Ultrasonic scanning equipment has become a very important non-invasive medical diagnostic tool. (circa 1971) [130]

Night Attack Capability

Sparrow All-Weather, Night-Attack Capability. The first successful all-weather, night attack was completed by VMF (N)-542 with Sparrow I. The target was destroyed. (1955) [135]

Optical Dome Material Work

Since the first infrared-guided Sidewinder missile flew in the 1950s, China Lake has developed domes with improved durability to protect seekers' delicate optics. Infrared domes must survive high-speed collisions with rain, sand particles, and bugs. High-acceleration heating can cause shattering from thermal shock. Early Sidewinders had a large, blunt glass dome that proved inadequate in rainy Vietnam. In response, China Lake built an artificial rain field at their Supersonic Naval Ordnance Research Track where domes were evaluated in supersonic raindrop collisions. From this work, hot-pressed magnesium fluoride was identified as a superior material, and in the last three decades it became the most widely used dome material and was installed in approximately 100,000 air-to-air missiles. In response to shortcomings regarding thermal shock, China Lake built the T-range facility where a ceramic dome could be subjected to simulated heating profiles. As new materials, such as spinel and sapphire, became available and were tested, sapphire became a material of choice. A research program at China Lake in the 1990s further identified methods to alter the sapphire crystal to improve its high-temperature strength. In the 1980s, China Lake marshaled leading laboratories in academia and industry to identify new, durable materials for long wave (8- to 12-micrometer wavelength) seekers. Out of this effort, by 1990, chemical-vapor-deposited diamond was identified as the most promising material. In a decade-long effort, diamond was taken from a microscopically thin laboratory curiosity to millimeter-thick, centimeter-size windows capable of being tested on rocket sleds. Today, China Lake is exploring new frontiers in developing window materials with nanometer-size grains that might possess increased strength and increased ability to form complex shapes, and which open up the possibility of fabricating tough, composite windows. [161]

Soldering Technology

Sets National Standards. During the 1970s, China Lake pioneered a unified set of state-of-the-art soldering techniques, materials, and processing technologies to ensure the production of high-quality, high-reliability electronic modules for military systems. China Lake also developed WS-6536, the DOD soldering specification. This led to a set of highly successful Soldering Technology Seminars and training courses that were regularly presented and hosted at China Lake from 1976 to 1993. Industry sent representatives to China Lake for training and certification. In 1993 the training course was transferred to industry through a CRADA between WD and Comarco, Inc. The soldering technology and techniques developed under this program led directly to today's high-quality, high-reliability, electronic systems in the commercial marketplace. (circa 1970 - 1993) [130]

Soldering School Developed Curriculum Used Throughout DOD. Formal soldering technology activity began in 1966. The military specification that evolved from this was subsequently applied throughout the DOD. This specification has been credited with saving DOD countless millions of dollars by forcing discipline into soldering programs. Because of that specification, the Soldering Technology School was established in 1977 to train contractor and government personnel in the requirements of weapon specifications and techniques. With the advent of MIL-STD-2000, the school was in the forefront of soldering technology, developing the curriculum used throughout the Defense Department. (circa 1970 - 1993) [141]

Video Cameras

Stop-Action. Electromechanical Shuttered. This invention was originated in 1975 by China Lake test range personnel to provide non-smeared stop-action images of high-speed video events to allow accurate position versus time measurements. This reduced cost compared to high-speed film cameras. A patent was awarded in 1977. The method was originally developed for vidicon tube cameras, but methods to achieve the same results with charge coupled-device (CCD) video cameras were also developed. During the late 1970s and the early 1980s, the technology was transferred to a commercially available multispectral video camera (a stop action camera for sports training). (circa 1975 - 1985) [158]

Direct Fleet Support

Vietnam Laboratory Assistance Program (VLAP)

On-Sight Problem Solving, Consulting/Liaison. Throughout the Vietnam War, China Lake supported the operations through the VLAP, providing analyses, weapons, support equipment, and operational support, including sending China Lake civilian personnel to provide immediate, on-sight consulting and liaison. [167]

Sea Chaparral and Shrike. Literally hundreds of rush projects were carried out under VLAP, including development of a specialized TDD for Standard ARM and deployment of the Sea Chaparral and Shrike-on-Board systems for ship self-protection during Vietnam. [167]

Urgent Problems—Quick Response Solutions. China Lake provided customized direct support for the special warfare systems; everything from swimmer weapons and non-irritating face paint sticks to specialized weapon systems, night-vision devices, and liquid explosives. [167]

VLAP 50 Problems Solved. VLAP was initiated in 1966 to provide scientific/technical advisors to the Fleet and the Marines in the Vietnam War. Tasks were of a quick-response nature—quick fixes, typically inexpensive, to emergent problems. China Lake was the west coast coordinator of the program until 1970. Throughout the conflict, the Center provided on-scene support, backed by design effort at China Lake. VLAP ended in 1972 but served as a model for the still-going NSAP (Navy Science Assistance Program). Some 50 tasks were addressed by China Lake personnel. Included were a small ground beacon for use by ground troops in identifying themselves to A-6 attack aircraft (1968), map illuminators (1969), hand-emplaced FAE canisters for mine clearance (1970), and an interim lightweight gun pod for the Marines. [141]

Crew Systems

Aircrew Safety

Aircrew Escape Propulsion. China Lake/NOTS began emergency aircrew escape work in 1957 with the Rocket Assisted Personnel Ejection Catapult (RAPEC), the first operational rocket catapult used by the armed forces. The improved RAPEC III followed in April 1958 and was installed in the A-4 aircraft. During the 1960s and 1970s, China Lake worked on a rocket catapult for the F-111 aircraft; extraction rockets for rapid drogue-chute deployment; a dual-mode rocket catapult system, which prevented rocket ignition if the aircraft was in an adverse roll or pitch attitude; a personnel extraction rocket system for the Cobra helicopter; parachute-extraction rockets; and airframe retro-rockets for the CH-46 helicopter escape system. China Lake also experimented with underseat thrust-vector-controlled rocket motors, which corrected for misalignment and pitching moments at ejection. [151]

Parachutes. China Lake was instrumental in space crew safety projects involving egress and personnel parachute systems. The Center used its Supersonic Naval Ordnance Research Track (SNORT) for specialized testing. Realistic, high-speed testing of ejection systems was a major area of T&E work at China Lake with its four-mile-long SNORT dual-rail supersonic track. SNORT was the test facility for most of the Navy's aircraft-ejection systems, as well as for Air Force aircraft and the Gemini spacecraft. In addition, specialized parachutes were developed for the Galileo probe, shuttle boosters, and recovery systems. [167]

Special Weapons and Projects

Antarctic Development Squadron Six (VXE-6)
A theory advanced by RADM Richard E. Byrd that "... aircraft alone could triumph over Antarctica" has been proven by a Point Mugu tenant, VXE-6. VXE-6 provides air support for scientific explorations and research in Antarctica sponsored by the National Science Foundation as part of the Navy's Operation Deep Freeze. The squadron was established in 1955 with a basic mission of providing airlift operations. On October 31, 1956, a C-47 named "Que Sera Sera" became the first plane to land at the South Pole. Aboard was a party of seven men, including RADM Dufek, who became the first Americans at the South Pole and the only men to set foot there since the Amundsen/Scott expeditions in 1911 and 1912. In 1957 and 1958, scientists from 12 countries conducted ambitious programs on the continent and sub-artic islands studying oceanography, glaciology, meteorology, seismology, geomagnetism, the ionosphere, cosmic rays, auroras, and airglow. With the success of the program, the U.S. Congress authorized an indefinite continuance of the program. A vast unknown area of the world was charted, new island stations established, and a wealth of scientific information gathered. VXE-6 flew some of the longest logistic and exploratory flights ever made in Antarctic history.

After 44 years of service, VXE-6 was deactivated in a March 27, 1999 ceremony at NAS Point Mugu. The mission was then taken over by the U.S. Air Force. VXE-6's annual deployments to Antarctica, accomplished many firsts. In 1958, a UC-1 made the first "wheels on dirt" landing in Antarctica. In 1964, an LC-130F conducted the first demonstration of Trimetrogon photography to map the Antarctic continent. In 1978, VXE-6 was awarded the Navy Unit Commendation for evacuating five Soviets critically injured in the crash of an IL-14 transport aircraft. The rescue flights covered 3,650 miles. During its service, VXE-6 transported more than 195,000 passengers, 240 million pounds of dry cargo and almost 10 million gallons of fuel to sites in Antarctica. Twenty-five Navy personnel and one Marine died while carrying out operations. [50]

Bombardment Aircraft Rocket (BOAR)
BOAR was a 30.5-inch rocket developed at China Lake/ NOTS. It was a rocket-propelled ballistic standoff weapon tipped with a nuclear warhead. BOAR was designed to be launched from a high-performance aircraft in a low-level loft and escape maneuver. This maneuver, combined with the weapon's rocket propulsion, would provide the necessary safe-separation distance to protect the aircraft and pilot from the blast of the nuclear warhead itself. China Lake/NOTS was responsible for developing the non-nuclear components of the weapon and for the automatic weapon-release computer used in the loft-launch technique. This technique was developed by VX-5 at China Lake. Safe separation of the BOAR from the launch aircraft was a technical problem. The loft maneuver pushed the propeller-driven test aircraft and the pilots to the limits. Engineers used scale models and a smoke box to study the airflow around the weapon and aircraft and verified those scaled results with tufts of yarn attached to the actual weapon during captive flight. BOAR, deployed with the Navy in 1956, was in service until 1963. [144]

Caleb
Airborne Satellite/Probe Launching Systems Used Around the World. Outgrowths from the NOTSNIK experimental work included the Caleb airborne satellite-/probe-launching system and the Microlock portable satellite tracking stations, which were deployed around the world and supported the Explorer Program. China Lake also participated in early strategic-defense and space-research projects with the development of probes, propulsion systems, and sensors. (circa 1961) [156]

Cast Glance High-Altitude Photography
During the 1970s Point Mugu developed Cast Glance, a unique in-flight system for long-range, high-altitude photography. Featuring a focal length of up to 120 inches, low-light-level video technology, and the ability to stabilize subject images on the film, the system was used to support tests of Harpoon, Tomahawk, and SeaSparrow, as well as Air Force ICBM and satellite launches. (circa 1970) [136]

Cable-Controlled Underwater Recovery Vehicle (CURV)
Deep-Water Diving Vehicle. China Lake developed a remote controlled diving vehicle designed to recover torpedoes. It was successfully used in 1966 to recover a lost nuclear weapon in deep water off the coast of Spain. (circa 1966) [156]

Deep Jeep
China Lake developed the first U.S. manned submersible to descend more than 2,000 feet. (circa 1964 - 1965) [156]

High-Altitude Probes
In the 1960s, Point Mugu helped develop a number of high-altitude probes. The Sidewinder-Arcas system was designed to lift a 10- to 15-pound payload to approximately 350,000 feet. Sparoair II, was designed to lift a 40-pound payload to 100 miles. The Terrier/NOTS-551 vehicle, developed in conjunction with China Lake, could lift a 50-pound payload to 450 miles. Perhaps the most unique was the Hydra-Iris, which used a sea-launching technique. The goal was to launch a 100-pound payload to 175 nautical miles. [50]

Marlin
NOTS demonstrated a submarine-launched bombardment missile in 1957. [145]

Mercury
Point Mugu provided planning support to NASA for Project Mercury, the first manned orbiting space capsule. Mugu supported the Gemini and Apollo manned space programs in the 1960s. (circa 1960) [136]

Moray
Moray was a submersible two-man deep diving test vehicle to explore concepts leading to small interceptor submarines. Many new approaches were evaluated, including a free-flooding hull, syntactic foam flotation material, innovative control concepts, and sensor systems. Test dives demonstrated operability. The original concept was for an undersea fighter aircraft. (circa 1963) [141]

NOTSNIK
One of the First in the U.S. In the wake of the Soviet Sputnik launch, China Lake got into the space race and developed the quick-response NOTS Project, also known as NOTSNIK, and built a vehicle to put a satellite in orbit from a TACAIR, which launched one of the first U.S. satellites. (circa 1958) [167]

NOTTY
Porpoise Project. China Lake was talking to dolphins and studying the way fish swim in the early 1960s. Project "Notty" originated at China Lake in 1962 and was tested at Point Mugu. Tanks were built near the entrance of the Mugu Lagoon, where the animals were trained for such high-risk tasks as deep-water recovery and explosives placement. Studies were conducted involving sonar, tracking, and hydro-dynamics. (circa 1962 - 1964) [136]

Polaris
Polaris is one of China Lake's most significant areas of accomplishment in Fleet ballistic missile support. The Polaris studies conducted by China Lake were instrumental in the development of the concept and the weapon system, and China Lake played a crucial role in rocket motor testing (Skytop) and underwater-launch testing (Pop-Up). The first successful underwater-launched Polaris firing was in the early 1960s. The T&E role continues to be significant, as witnessed by the huge Trident II motor test facilities opened in 1986. [145]

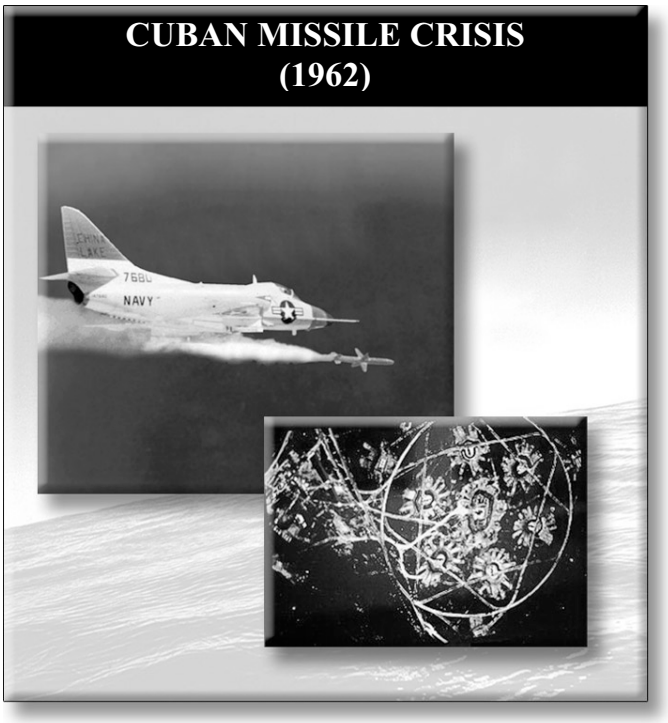
Satellite Interceptor Program (SIP)
China Lake was the first to demonstrate a concept for an experimental SIP. SIP underwent a test launch series from both aircraft and the ground using the air-launched techniques developed for NOTSNIK. (1962-63) [152]

Swimmer
Underwater Demolition Team. Special Warfare Program (Swimmer). This program carried out quick-response efforts in support of underwater demolition team operating from 1965 to 1972. A large array of specialized devices was developed including the Actuation Mine Simulator (AMS) on which work commenced in 1965. This device for training and minesweeping was highly successful. [141]

Weather Modification
Between 1949 and 1978 China Lake developed concepts, techniques, and hardware that were successfully used in hurricane abatement, fog control, and drought relief. Military application of this technique was demonstrated in 1966 when Project Popeye was conducted to enhance rainfall to help interdict traffic on the Ho Chi Minh Trail. (1966) [167]

General

VIP Quotes
Office of the Chief of Naval Material 1970s. In extensive peer-rating surveys conducted by the Office of the Chief of Naval Material in the 1970s, China Lake was rated the top Navy laboratory. [141]



Weapons and Weapon Systems

Night Attack Capability

First Real-Time Infrared (IR) Night Display of Targets. Beginning in 1962, China Lake developed the hardware to provide the Fleet with an effective night-attack capability using FLIR devices. One FLIR display system demonstrated the first real-time IR night display of targets. The technology evolving from this early effort led to China Lake involvement in the development of the Night-Attack System. (circa 1961) [167]

Shrike

Early Shrike Effort (ESE) "Easy" Program. Two Hundred Preproduction Missiles. In 1962, the Cuban Missile Crisis—with Soviet medium-range nuclear missiles set up in Cuba—was complicated by the arrays of radar defending the missile sites. The U.S. had no antiradiation missile, but Shrike was under development at China Lake. An urgent message was received to provide Shrike missiles at once, even though the system was not yet at the end of development. Of the 200 missiles built, about half were produced at China Lake and the others at Texas Instruments, with China Lake and TI working in concert. Alternate guidance sections had to be designed "from scratch" on an urgent basis. Even though most of the hardware was built by engineers and technicians in a small room on the floor of China Lake's Hangar One, system reliability was phenomenal. After the missiles had been deployed for a number of years at Cherry Point, some were sent back and fired in training exercises. Every one worked properly. [141]

Test and Evaluation/Range Support

Extreme-Altitude Vertical Test Shot

As part of the Naval Ordnance Test Station (NOTS) space research program, China Lake was the first to conduct an extreme-altitude vertical test of a vehicle launched from an aircraft. The vehicle, called "Caleb" (NOTS EVII), garnered a (classified) world record. [152]

Electronic Warfare

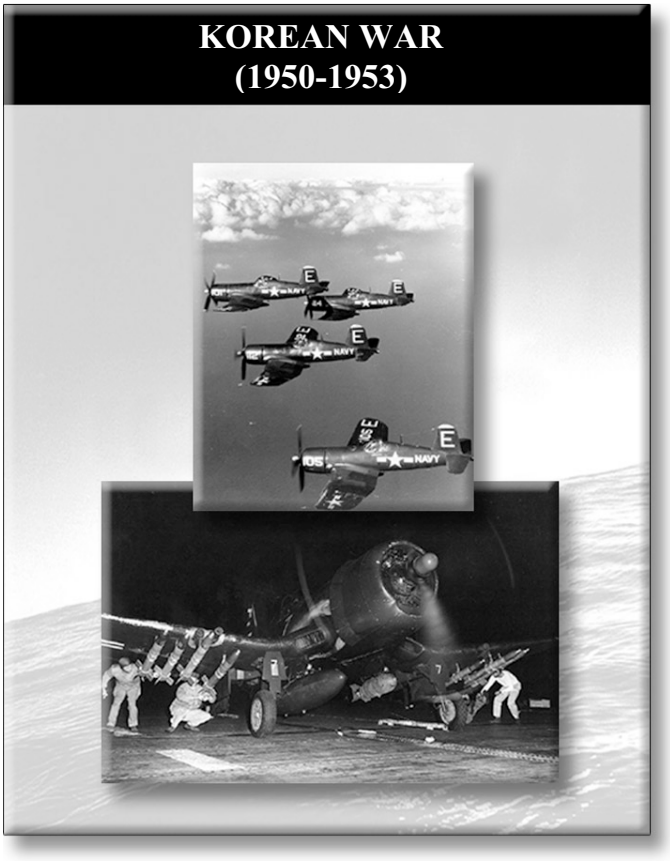
Cuban Missile Crisis Quick Response

A midnight call was made from the Air Force to Point Mugu on a Saturday night in October 1962 requesting immediate assistance for assembling and installing AN/ALQ-35 Jammers in pods on B-47 bombers based at Homestead Air Force Base, Florida. Within six hours, all the hardware was collected and loaded onto an A-3, along with technicians. In the midst of preparations it was learned that the Russians had just agreed to remove their missiles from Cuba. [153]

General

John F. Kennedy Visit

President John F. Kennedy stressed the ICBM "missile gap" the "space race" with the Soviet Union, and the need for preparedness during this 1960 presidential campaign. In the summer of 1963 he visited Point Mugu and China Lake for a first hand inspection, and some 60,000 people turned out to greet him. His entourage included many high-level dignitaries. China Lake provided an extensive firepower demonstration on the G range. (1963) [136]



Weapons and Weapon Systems

Antisubmarine Weapons
The 12.75-inch antisubmarine rocket "Weapon A" entered service. [145]

Bumblebee
Bumblebee was a significant post-war missile test series conducted at China Lake and Point Mugu. The objective was to develop a ramjet missile that could be launched from ships against high-altitude aircraft and be guided to its aerial target along a radar beam. Between mid-1945 and 1952, a swarm of Bumblebees flew over China Lake. In 1947 the first successful subsonic beam-riding flight was made at NOTS when a roll-stabilized control test vehicle followed a fixed radar beam for 16 seconds. A historic milestone in guided missile development was passed in March 1948 when two successful supersonic beam-riding flights were conducted at NOTS. These were the world's first successful beam-riding flights at supersonic velocities. [29]

Guidance and Control
Sparrow. The AN/MPQ-14 Marine close-support guidance system for ground forces was developed at Point Mugu. In this system an aircraft is controlled by signals from a ground radar station so as to fly a desired course and release its bombs at the proper time. This system was successfully used by the Marines in the Korean War. [135]

Rockets
Korea/Vietnam. Prime Strike Weapon. Mighty Mouse, one of the Station's major contributions to defense, was used by the Army, Navy, Air Force, and Marine Corps. It was also used extensively in Korea and Vietnam in anti-personnel, antimateriel, and flak-suppression strikes. The Army, using the slow-roll modification developed by China Lake, made Mighty Mouse one of its prime strike weapons. Mighty Mouse became, and continues to be a principal helicopter weapon in all services. [145]

Lark
First Guided Missile Kill. A Lark fired from Point Mugu on December 18, 1951, made the first guided missile "kill" against an airborne target, scoring a direct hit on a F6F-5K, a WW II fighter converted to a radio-controlled drone. Loon, Lark, and Gorgon were the major missile T&E programs at Point Mugu during the late 1940s and early 1950s. (1951) [136]

Winston Churchill. Point Mugu made the first guided-missile kill of an aerial target, which was accomplished using a CTV-N-10 Lark. A photograph of the kill was shown to Winston Churchill by President Truman. (1951) [135]

RAM
Korea. Produced/Delivered Rocket in Just 29 Days. This China Lake quick-response capability made possible efforts such as Project RAM, which developed, produced, and delivered the 6.5-inch tank-killing rocket to Korea in just 29 days in 1950. [167]

Michelson Laboratory Hall Turned Into Crash Production Facility. During the Korean War an urgent need arose, just after the North Korean invasion, for something that could stop the North Korean tanks with five-inch armor. Within 29 days, China Lake developed a shaped-charge warhead to match with the five-inch high-velocity aircraft rocket motor and produced quantities of the resultant weapon, which was in service in Korea. This antitank aircraft rocket was also called RAM. For a time, the whole main hall of Michelson Laboratory was turned into a fuze-production shop with clerks as well as engineers working on the "production line." [141]

Sidewinder Missile is Potent, Reliable
In the early 1950s, one of the nation's most potent, most reliable, and simplest weapons was born under a cover of deepest secrecy at a Navy test facility in California's Mojave Desert. It was known by the code name "Local Project 612." Some military experts maintain that an updated version of the Sidewinder continues to be the nation's most effective and successful weapon. While many more expensive weapons systems have come and gone, the Sidewinder remains the fighter pilots' weapon of choice. The Sidewinder saga began in the late 1940s, when the Air Force and the Navy set the specifications for a new kind of missile. It had to perform in all weather conditions and had to be able to kill enemy aircraft by striking them head on. Dr. William McLean, physicist, led the development team. He concluded that what would work

was a simple, rocket-propelled bomb with a heat-detecting device built into its nose so that it would automatically home in on the intense heat of jet engine exhaust. Working part of the time in his garage, Mr. McLean designed about 85% of the missile. It had a total of nine moving parts and its "brain" consisted of seven radio tubes. It used gas pressure from burning rocket fuel to move its control fins and to generate a small amount of electricity. There were no batteries to wear down, no hydraulics to leak or freeze, no precision-machined tolerances. "It had the mechanical complexity of a small washing machine combined with a table radio," recalls Howard A. Wilcox, Mr. McLean's principal assistant at the time. For his efforts on the Sidewinder, Mr. McLean received a $25,000 award from the government and a plaque from President Eisenhower. [162]

Sparrow

The Sparrow program began at Point Mugu in the 1950s and took several approaches in the development of an air-to-air combat weapon that could replace cannons and guns on fighter aircraft. Sparrow I was a short-range missile designed to ride a radar beam directed at the target by the launch aircraft. In 1951 the missile achieved the first successful test. In July 1952, the first prototype was air launched; the missile later that year achieved a direct hit on an Air Force QB-17 target drone. RADM C. C. Andrews (USN, Ret.) tells the story: "It was a far cry from a tactical weapon, but a great boost to the air-to-air missile program. To our knowledge, it was the first in the world to hit an aircraft. Mugu was on the leading edge of the missile age." In 1955, Point Mugu achieved a significant first when a Sparrow I was successfully launched against a high-speed KDU-1. In 1956, VA-83, the first aircraft squadron to be equipped with Sparrow I missiles, saw deployment aboard *USS Intrepid*. Sparrow II, a fully active, radar-guided missile, was air launched for the first time in 1952. That same year the supersonic Sparrow III program began, with the missile first launched from an F3H in 1956. In 1959 a successful target intercept was made from a F4H-1. In 1969 Point Mugu helped develop an improved warhead for the AIM-7F. In the 1970s testing continued on new guidance controls and the F-14/Phoenix test program began. [50]

First U.S. Kill of Airborne Target by an Air-Launched Missile. Sparrow I, with radar-beam-rider guidance, made the first U.S. kill of an airborne target by an air-launched missile. (1952) [136]

Spin-Stabilized Bombardment Rockets (SSBRs)

Immense Numbers Used. Immense numbers of SSBRs were employed during WWII for ship-to-shore barrages incident to amphibious operations. These rockets were developed and produced at China Lake. SSBRs were heavily used in the Korean War for shore bombardment. [141]

SWOOSE

2.75-Inch Experimental Plastic Rocket. The experimental rocket was 2.75 inches in diameter and designed to test the feasibility of replacing steel rocket casings with lighter-weight rocket-motor designs. This project was used to study the feasibility of using a glass-reinforced resin motor tube and the effects of the lighter-weight casing on rocket performance in terms of speed and acceleration. China Lake designed, developed, tested, and performed limited production of the conceptual missile. Exploratory development was initiated in 1952. Tests conducted at China Lake demonstrated that these plastic motors reached speeds in excess of 2,700 miles per hour in less than one second. [144]

Teamwork

"Here was teamwork at its utmost. Scientists, engineers, technicians, metal-benders, range crews, ordnancemen, and pilots—24 hours a day. We all operated on two hours of sleep." [46]

Testing and Evaluation/Range Support

Computer Revolution

In the early days, telemetry film assessment work required a phalanx of detail-minded employees to sit hour after hour, peering at test-film footage through microscopes, laboriously counting pulses, and writing measurements down. Workers complained of tedium and ruined eyesight. In 1946 the world's first fully electronic computer, the Electronic Numerical Integrator And Calculator (ENIAC), began operation at the University of Pennsylvania. NOTS staff were anxious to adapt the new machines to their needs. In 1950, two NOTS chemists designed and constructed an analog computer that was made of old radar and radio parts. The computer dramatically reduced the time necessary to calculate the theoretical performance characteristics of certain propellant compositions. China Lake's first centralized computer began operation in October 1951 when the new Reeves Electronic Analog Computer (REAC), "a mechanical brain that thinks in terms of 'things' rather than numbers," was set up in the hallway in Michelson Lab. By today's standards a clumsy device—requiring about 3,000 vacuum tubes to make it work—REAC was a marvel of efficiency back then and was used to perform early Sidewinder simulations and to accomplish such tasks as calculating the aerodynamic characteristics the rocket-assisted torpedo (RAT) would need under various ship-launching conditions. [49]

RAYDAC. In the early 1950s, Point Mugu had one of the first large digital computers ever built, RAYDAC (Raytheon Digital Computer), which was used as the nucleus of a real-time telemetry data reduction system. RAYDAC consisted of a large number of vacuum tubes and banks of mercury-filled acoustic delay lines. It was considered very advanced for that time and was showcased for visitors. [50]

Geophysics

Meteorological data are critical to test operations. In 1946 a weather observation and forecasting program was established at Point Mugu. Later, with the increased use of radar for tracking high-altitude missiles, meteorological measurements

of the upper air to obtain data for refraction correction became important. By 1959, range meteorological facilities were established throughout the Pacific and aboard range instrumentation ships. By 1960, a 24-hour a day, seven-day a week operation was providing information to altitudes in excess of 200,000 feet. Point Mugu was selected as the Meteorological Satellite Readout Station. [50]

Telemetry

The use of telemetry for gathering data during missile launches at Point Mugu began in 1946 and expanded until there were sites at Laguna Peak, San Nicolas Island, Santa Rosa Island, Point Arguello, Kokee Park and Barking Sands (Kauai), Tern Island, South Point, Ennylabegan (Kwajalein Atoll), and Canton Island. Also, there were seven ships and five EC-121 aircraft equipped with telemetry equipment. The aircraft flew missions from nearly every continent. In one instance, an EC-121 aircraft was used in the Strato Lab High operation out of Pensacola, Florida. For 14 hours the aircraft, via telemetry, monitored the vital statistics of two balloonists as they rose to an altitude of more than 102,000 feet in an open gondola. Telemetry systems at Point Mugu, Laguna Peak, and San Nicolas Island continue to provide efficient and reliable high quality support for air, surface, and space platforms with many of these tests involving multiple missiles, launch vehicles, and targets. Two extensively modified NP-3D aircraft Airborne now provide airborne telemetry support. These aircraft provide support for tactical, strategic, and space test operations on the Weapons Division test ranges and world-wide. [50]

Research, Science, and Technology

Technical Library--First Use of a Computer for Library Applications

Preceding Google by almost 50 years, the Technical Library at NOTS China Lake developed a computer system that could search a database by subject. Using an IBM 701 (the first mass-produced computer and Defense calculator) and the Technical Library coordinate index cards, Harley Tillit, father of modern computing at China Lake, is credited with conducting "the first subject search ever made by a digital computer" in 1954. Only 19 701s were installed nationwide. One unit went to IBM's world headquarters in New York. The eighth unit built was installed at China Lake. Tillit's research was in direct response to the need for cataloging and indexing vast collections of scientific and technical reports—a technical problem faced by all technical libraries in the 1950s. In 1953 China Lake implemented one of the first uniterm coordinate indexes—and the first on the West Coast. Half a century later, most bibliographic searching still relies on coordinate indexes. What happened at China Lake was one step in a long journey, but with that single step, a boundary was crossed. All that remained was to reduce the cost of computer time. In the 1960s, more sophisticated searching programs were developed using the IBM 7094 with a program called the Library Information Search and Retrieval Data System (LISARDS). [164]

Crew Systems

Aircrew Safety

Supersonic Naval Ordnance Research Track (SNORT) Tests Most of the Navy's Aircraft-Ejection Systems. China Lake has been significantly involved in aircrew safety RDT&E since the 1950s when it developed the RAPEC. RAPEC was developed as an outgrowth of China Lake expertise in propulsion systems and was widely fielded. Another ejection seat based on propulsion-system expertise was the Vertical-Seeking Subsystem. Realistic, high-speed testing of ejection systems has also been a major area of T&E work at China Lake, especially using the four-mile-long dual-rail SNORT supersonic track, which was the test facility for most of the Navy's aircraft-ejection systems, as well as for Air Force aircraft and the Gemini spacecraft. (circa 1950 - present) [156]

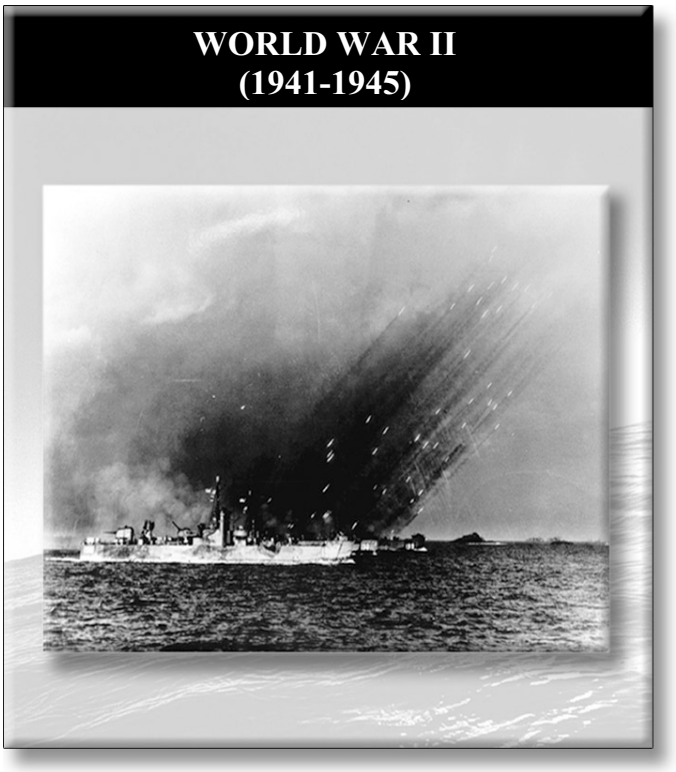
Aircraft Fire Control System (Mk 16). Released. [46]

Special Weapons and Projects

Elsie (TX 8/TX 11). Nuclear penetrator bomb released. [46]

Space Imagery

China Lake First to Develop Technique for Transmitting Images to Earth Electronically. China Lake developed a photographic technique applicable for satellite reconnaissance. The new technology allowed electronic images of the back side of the moon to be transmitted back to Earth. This technology used the same unique photographing techniques used on the NOTSNIK satellite. (circa 1950) [152]



Weapons and Weapon Systems

Bomb Racks/Directors

Mk 6 Mod 3, Mk 10, EX-1. Beginning in the 1940s, China Lake developed bomb directors such as the Mk 6 Mod 3, Mk 10, and the EX-1 (the most accurate of its day for single-seat attack aircraft), the bomb-director set AN/ASB-8, and fire-control systems Mk 8, Mk 16, and EX-16 (a high-performance system using a revolutionary computing technique). [145]

Regulus

First Submarine Launch. Regulus was born of the Navy's requirement for a submarine-launched, long-range bombardment weapon. The weapon came to Point Mugu for T&E in January 1949. Some of the first testing was conducted at San Nicolas Island, and the first submarine launch was made from *USS Tunny* in July 1953. Regulus became operational in 1955. Regulus became the largest single program in Point Mugu history in terms of manpower and facilities. It served as the forerunner for the Polaris submarine-launched ballistic missile (SLBM) program. (circa 1953 - 1955) [136]

Regulus II. Navy's First Supersonic Cruise Missile Capable of Delivering a Nuclear Warhead. Work on Regulus II began during the late 1940s, but it became operational in 1956 as the Navy's first supersonic cruise missile with a capability of delivering a nuclear warhead. It began operational testing at Point Mugu in June 1958. (circa 1949 - 1958) [136]

Bombardment Rockets

Significance. China Lake developed bombardment rockets that were capable of enhanced range and lethality. They were frequently used to provide fire support for amphibious landings and were also used in Vietnam. [145]

Forward-Firing Rockets

Significance. The Caltech/China Lake rocket program affected the outcome of WWII. China Lake's work in the early days of rocket development also laid the foundation for continuing successful efforts in rockets, missiles, propellants, warheads, launchers, and fire-control. [145]

Holy Moses

One of the First Forward-Firing Rockets. Rocket development and testing at China Lake began with the work on a version of the Caltech 3.5-inch AR, which was the first forward-firing rocket used by American troops during WWII. Within nine months after the Caltech/China Lake rocket program began, Fleet aircraft were equipped with this rocket. The 3.5-inch AR and the 5.0-inch Holy Moses were used extensively in Pacific Theater operations to weaken enemy resistance to the U.S. offensive. Holy Moses was also used in the Korean War. [145]

From Design to Combat in a Few Months. China Lake's record of quick-response accomplishments goes back to WWII. Collaborative efforts with Caltech made possible the design, development, testing, and production of Holy Moses five-inch rocket weapons within a matter of months; Holy Moses was operating in combat by August 1944. [141]

Land and Mine Clearing

China Lake developed a rocket-thrown line charge that permitted remote clearing of hazardous landing areas. For the first time, assault forces could launch amphibious operations over terrain cleared of mines and obstacles. Experience gained has contributed to the technological base of terrain-clearing weaponry now used by all U.S. services. The technology was also used in Vietnam. [145]

Mighty Mouse

Millions of Rockets Used. Early special-purpose rockets, developed at China Lake, were used for everything from propelling line charges to sampling atomic clouds. Literally millions of the 2.75-inch Mighty Mouse and 5.0-inch Zuni were fired in combat. [167]

Only Bullets Surpassed Use. The 2.75-Inch FFAR usually referred to just as the "2.75" and occasionally by its other name, Mighty Mouse, was used in incredible quantities around the world since its development at China Lake in the 1940s. In fact, more 2.75s have been fired than any other item of ordnance other than bullet-type ammunition. [141]

Sole Source for Rockets

All of the Navy rockets used in WWII, and all of the aircraft-fired rockets, were developed at China Lake. [152]

Tiny Tim
11.75-inch Tiny Tim was fielded. [46]

Targeting
TV Based Avionics. China Lake was involved in the early development of TV-based avionics, and following its early work on forward-looking infrared (FLIR) technology; China Lake was the lead in integrating FLIR systems into aircraft. [46]

Targeting and Fire Control. China Lake targeting and fire-control projects also include the CP-741/841 weapons computer, Navy Pave Knife laser designator, and the Angle-Rate Bombing System (ARBS). [46]

Test and Evaluation/Range Support

Bat
Bat, an air-to-surface glide bomb developed during World War II, was the country's first fully active-radar-homing missile. Launched from PB4Y patrol bombers in the Philippines, Bat achieved its first combat success in April 1945 against Japanese shipping and picket boats in a narrow harbor. Through the waning months of the war, Bats were used against a variety of targets in and around the Sea of Japan. In 1946, 300 Bats were assigned to Point Mugu to be tested as potential service weapons. In the early 1950s several Bats were modified and tested as antiradiation missiles. The antiradiation-homing Bat II contributed to the development of later antiradiation missiles, including Shrike and Corvus. [136]

Lark
The China Lake and Point Mugu ranges supported Lark, a surface-to-air, radio-controlled subsonic missile intended for shipboard launch against aircraft. Lark was 14 feet long and 17 inches in diameter and powered by a liquid propellant rocket engine. It was designed to be launched by two strap-on 1,000-pound-thrust, jet-assisted-takeoff units and then radio-controlled to intercept. The test objective was to determine stability and control characteristics, to correct any faults in flight and control, and to provide data for missile evaluation. In early 1948 all Lark testing was shifted to the Naval Air Missile Test Center at Point Mugu. The missile airframe was tested at Point Mugu in the late 1940s and achieved a number of significant firsts in radar guidance. In one test, guidance was provided by two anti-aircraft radars: one maintained line-of-sight direct to the target, while the other directed the missile. The Lark was directed along a radar line-of-sight path for 20,000 yards with a maximum deviation error of approximately 50 yards. On September 21, 1949, for the first time, a Lark rode a moving radar beam, remaining within 0.75 degree of the radar beam for approximately 50 seconds. Three months later, a Lark successfully guided toward an aircraft using, for the first time, an optical missile and target tracking system, and employing an automatic electronic command signal computer that derived intelligence from an optical tracking device. On December 18, 1951, for the first time, a guided missile made a contact hit on an aerial target. Previous kills had been a result of the missile passing within lethal range. [50]

Loon
The Loon was the U.S. version of the German V-1 buzz bomb; Point Mugu conducted extensive Loon testing in the 1940s. The Loon was a pulse-jet propelled, midwing monoplane. To propel the Loon to flying speed, the XM-1 catapult launcher was first used. The first live firing took place in 1946, but the project was challenging (the Loon dived abruptly). To correct the problem, engineers studied vibration, autopilot, and elevators. An interesting story emerged. The first hint that the elevators might be a factor came from an outside source—the *Los Angeles Times*. At a news media open house, a photographer took a picture of the Loon at just the right angle. When the photo appeared in the Sunday *Times*, the operations officer (later rear admiral) studied the photo and noticed that the problem was not in balance, as had been suspected, but was in the launching configuration. To correct the problem, a pitch rate gyro caging device was soon created. From 1947 to 1949, great progress was made in improving flight performance. The Loon had numerous firsts: first launch from a surfaced submarine, *USS Cusk* in 1947; and the first zero launch from *USS Norton Sound* in 1949. Guidance and control functions were enhanced and the Loon evolved and produced invaluable advances that set the stage for surface-launched weapons of far greater range, accuracy, and lethality. [50]

Regulus
Regulus I was a 500-mile-range, surface-to-surface, subsonic, guided (cruise) missile that began testing at Point Mugu in 1949. Regulus was the size of fighter aircraft and equipped with retractable landing gear. In the 1950s Point Mugu developed launchers for dummy missiles to be fired from the submarine *USS Tunny*. Point Mugu also developed ejection systems and special cradles. In 1955, after more than 200 flight tests, Regulus I became operational on submarines and cruisers. Testing was conducted to see whether the weapon system could meet the operational requirement of a circular error probability (CEP) of 1,000 yards at a guidance range of 100 nautical miles, and to determine the origins of errors. In 1956, Regulus I made its first inland flight over the California coast, successfully impacting at Salton Sea. The Regulus II program begun in 1956 was the Navy's first supersonic missile with nuclear capability. Fifty-seven feet long and weighing 21,000 pounds, Regulus II was boosted at launch by a rocket motor that was jettisoned, and then powered by a 10,000-pound-thrust turbojet engine to a speed of Mach 2. Regulus II had landing gear and thus could be recovered. In 1958 the missile was successfully launched from the submarine *USS Grayback*. The Regulus II program became the largest single program in Point Mugu history in terms of manpower and facilities. The Polaris program replaced Regulus in 1958. [50]

Test and Evaluation (T&E)

Navy's Proving Ground. NOTS provided T&E for Caltech rockets. NOTS served as the Navy's proving ground for all aviation ordnance. [167]

More Than 3,000 Test Flights. Point Mugu was a leader in the test, evaluation, and operational use of airborne targets from its inception. It was a leader in turning the simple WWII antiaircraft targets into systems that realistically simulated real threats. Point Mugu also tested drones. From 1946 to 1958 more than 3,000 test flights were made with more than 30 different models. (circa 1946 - 1958) [136]

Solar Yaw Camera. While designing forward-firing aircraft spinner rockets, NOTS and Caltech engineers fired thousands of rockets on the China Lake ranges. New methodology and instrumentation were called for to gather the necessary data from these test firings. Most urgently needed was a device that could record a spinner rocket's flight from launch to impact as seen from the rocket's point of view. Dr. Ira Bowen, working with an idea from another Caltech scientist, W. R. Smythe, developed the solar yaw camera, essentially a pinhole camera mounted in the nose of a spinner rocket. The camera began operating when the rocket fired, and the rocket's rotational movement advanced a film strip continuously past the light-admitting aperture at a rate of one exposure for each rotation. The angle of the sun's rays striking the film produced lines of varying lengths, and analysis of these lines yielded complete position information for the rocket at any moment during its flight. The solar yaw camera provided baseline data for the shape and balance of a particular round, and—when augmented by known trajectory information—enabled a determination of aerodynamic forces during and after rocket burn. [165]

ACRONYMS

3rd MAW	Third Marine Aircraft Wing
A-	attack (aircraft)
AAAM	Advanced Air-to-Air Missile
AARGM	Advanced Antiradiation Guided Missile
AAW	anti-air warfare
ACE	AMRAAM Captive Equipment
ACETEF	Air Combat Environment Test and Evaluation Facility
ACIMD	Advanced Common Intercept Missile Demonstration
AD	Aircraft Division
ADAM	Advanced Development Attack Model
ADDB	Air Deliverable Depth Bomb
ADSI	Air Defense Systems Integrator
AEA	Airborne Electronic Attack
AEC	Atomic Energy Commission
AEDC	Arnold Engineering Development Center
AESA	Active Electronically Scanned Array
AFB	Air Force Base
AFD	arming-firing device
AFWTF	Atlantic Fleet Weapons Test Facility
AGL	above ground level
AGM	air-to-ground missile
AIAA	American Institute of Aeronautics and Astronautics
ALE/ALQ	electronic warfare
ALSS	Aviation Life Support System
ALVRJ	Air-Launched Low-Volume Ramjet
AMRAAM	Advanced Medium-Range Air-to-Air Missile
AMS	Actuation Mine Simulator
AN	Army/Navy/DOD
AORR	Aviation Ordnance Readiness Review
AOT	advanced oxidation technology
AOTD	active optical target detector
AP	Alpha Papa
AP	ammonium perchlorate
APAM	antipersonnel/antimateriel
AQM	airborne target
ARBS	Angle-Rate Bombing System
ARM	anti-radiation missile
ARP	Anti-Radiation Projectile
ARPA	Advanced Research Projects Agency
ASRAAM	Advanced Short-Range Air-to-Air Missile
ASROC	antisubmarine rocket
ASW	antisubmarine warfare
ATA	Automatic Target Acquisition
ATAR	Antitank Aircraft Rocket
ATARS	Advanced Tactical Airborne Reconnaissance System
ATD	Advanced Technology Demonstration
ATFLIR	Advanced Targeting Forward-Looking Infrared
ATIGS	Advanced Tactical Inertial Guidance System
ATR	automatic target recognition
AV	attack, vertical/short takeoff and landing
AWB	Air Weapons Bulletin
AWL	Advanced Weapons Laboratory
B-	bomber (aircraft)
BAE	British Aerospace
BARSTUR	Barking Sands Tactical Underwater Range
BAT	Bomb Assist Team
BDA	battle damage assessment
BIT	built-in-test
BLM	Bureau of Land Management
BLU	bomb, live unit
BMIC	Battle Management and Interoperability Center
BOAR	Bombardment Aircraft Rocket
BOMROC	bombardment rocket
BQM	aerial targets/threat
BRU	bomb rack (or release) unit
BSURE	Barking Sands Underwater Range Expansion
BuOrd	Bureau of Ordnance
C-	cargo (aircraft)
CAG	Carrier Air Group
CAINS	Carrier Aircraft Inertial Navigation System
Caltech	California Institute of Technology
CAT	catapult-launched
CAW	Center for Asymmetric Warfare
CAX	Combined Air Exercise
CBU	cluster bomb unit
CCD	charge coupled-device
CDI	cast ductile iron
CDR	Critical Design Review
CENTCOM	Central Command
CEP	circular error probability
CFC	chlorofluorocarbon
CFF	call for fire
CIL	computer-in-the-loop
CINC	Commander-in-Chief
CIWS	Close-In Weapon System
CLC	Command Launch Computer
CLPL	China Lake Propulsion Laboratories
CMBRE	Common Munitions Built-In-Test Reprogramming Equipment
CMRTR	Cruise Missile Real-Time Retargeting
CNO	Chief of Naval Operations
COMNAVAIRLANT	Commander, Naval Air, Atlantic
COMOPTEVFOR	Commander, Operational Test and Evaluation Force
COMPUTEX	Composite Unit Training Exercise
CONOPS	concept of operations
CONUS	continental United States
COTS	commercial off-the-shelf
CRADA	Cooperative Research And Development Agreement
CRALTS	Common Rack And Launcher Test Set
CRIB	Controlled Reference Image Base
CSS	Coastal Systems Station
CSSQT	Combat System Ship Qualification Trial
CURV	Cable-Controlled Underwater Recovery Vehicle
CVW	Carrier Air Wing
CY	calendar year
DACS	divert and attitude-control system
DAMASK	Direct Attack Munition Affordable Seeker
DARPA	Defense Advanced Research Projects Agency
DCGS	Distributed Common Ground Station
DCRS	Digital Camera Receiving System
DLA	Defense Logistics Agency
DMSU	data storage memory unit
DOD	Department of Defense
DON	Department of the Navy
DOT&E	Development Operational Test and Evaluation
DPSS	Digital Precision Strike Suite
DRL	Descent rate limiter
DSMAC	digital scene matching area correlation
DSU	detecting device unit
DT	developmental testing
DTRA	Defense Threat Reduction Agency
EATS	Extended Area Test System
ECM	electronic countermeasure
ECR	Electronic Combat Range
EDL	Entry, Descent, Landing
EER	Extended-Extended Range
eESWA	Enterprise Expeditionary Strike Warfare Architecture
EFE	Exploding Foil Initiator
EGI	embedded GPS/INS
EIPT	Energetics Integrated Product Team
EIS	Environmental Impact Statement
ELINT	electronic intelligence
EMD	Engineering and Manufacturing Development
EMP	electromagnetic pulse

ENIAC	Electronic Numerical Integrator And Calculator
EOB	electronic order of battle
EOC	early operational capability
EOD	explosive ordnance disposal
EPA	Educational Partnership Agreement
ERA	Extended Range ASROC
ERASE	Electromagnetic Radiating Source Elimination
ERDL	Extended Range Data Link
ERGM	Extended Range Guided Munition
ESE	Early Shrike Effort
ESSM	Evolved SeaSparrow Missile
ETIRMS	Electronic Warfare Tactical Information Report Management System
EVMS	Earned Value Management System
EW	electronic warfare
EWDS	Electronic Warfare Database Support
F/AATD	Fighter/Attack Avionics Targeting Demonstration
FAA	Federal Aviation Administration
FAC	forward air controller
FAE	fuel-air explosive
FAF	Finnish Air Force
FAILSAFE	Fleet Air Introduction Liaison of Survival Aircrew Flight Equipment
FBE	Fleet Battle Experiment
FBE-J	Fleet Battle Experiment-Juliet
FDE	Forward Dissemination Element
FFAR	folding-fin aircraft rocket
FFCS	Fuze Function Control Set
FLC	Federal Laboratory Consortium
FLIR	forward-looking infrared
FME	foreign material exploitation
FMS	foreign military sales
FMU	fuze munitions unit
FOG	fiber-optic gyro
FON	Fiber Optic Network
FOSE	Federal Office Systems Exposition
FSAT	full-scale aircraft target
FSI	Fleet Support Initiative
FTI	Fast Tactical Imagery
FWST	Fleet Weapons Support Team
FY	fiscal year
GBU	guided bomb unit
GCS	guidance control section
GFE	government-furnished equipment
GP	general purpose
GPS	global positioning system
GRIPS	GPS Reporting Information Package System
GUI	graphical user's interface
HAHO	high-altitude, high-opening
HALO	high-altitude, low opening
HAP	High-Altitude Performance [program]
HAPLSS	High-Altitude Parachute Life-Support System
HARM	High-Speed Antiradiation Missile
HARM-U	HARM University
HART	Hornet Autonomous Reactive Targeting
HIPER	high-performance
HIVAS	High-Velocity Airflow System
HMMWV	high-mobility multipurpose wheeled vehicle
HOL	higher-order language
HPM	high-power microwave
HRM	high resolution mapping
HSFD	Hydrostatic Firing Device
HSMST	high-speed maneuvering surface target
HTSF	hard-target smart fuze
HVAR	high-velocity aircraft rocket
HWIL	hardware-in-the-loop
I MEF	First Marine Expeditionary Force
IBAR	Integrated Battlespace Arena
ICAP	improved capability
ICS	intercommunications system
ICWD	interim continuous wave detector
IDECM	integrated defensive electronic countermeasure
IDM	improved data modem
IFPDAS	In-Flight Physiologic Data Acquisition System
IHAT	Integrated Hypersonic Aeromechanics Tool
IHPRPT	Integrated High Payoff Rocket Propulsion Technology
ILS	integrated logistics support
IM	insensitive munitions
IMU	inertial measurement unit
INS	inertial navigation system
IOC	initial operational capability
IOCP	improved operator control panel
IPT	Integrated Product Team
IR	infrared
IRR	Integral Rocket/Ramjet
ISR	intelligence, surveillance, and reconnaissance
ITCS	Integrated Target Control System
ITEC	Interoperability Test and Evaluation Complex
ITV	Integration Test Vehicle
IWSR	Integrated Weapon Systems Review
JANNAF	Joint Army-Navy-NASA-Air Force Interagency Propulsion Committee
JASSM	Joint Air-to-Surface Standoff Missile
JATO	jammer techniques optimization
JCIET	Joint Combined Interoperability Evaluation Team
JDAM	Joint Direct Attack Munition
JFCOM	Joint Forces Command
JGSDF	Japan Ground Self-Defense Force
JHMCS	Joint Helmet Mounted Cueing System
JIMS	Joint Improved Mk 82 Series
JMEM	Joint Munitions Effectiveness Manual
JMPS	Joint Munitions Planning System
JNTC	Joint National Training Center
JPL	Jet Propulsion Laboratory
JSADLT	Joint Services Air Defense Lethality Team
JSF	Joint Strike Fighter
JSOW	Joint Standoff Weapon
JSSA	Joint System Support Activity
JT&E	Joint Test and Evaluation
JTAT	Jammer Technique Analysis and Tactics
JTCG/AS	Joint Technical Coordinating Group on Aircraft Survivability
JTCG/ME	Joint Technical Coordinating Group for Munitions Effectiveness
JTFEX	Joint Fleet Exercise
JTIDS	Joint Tactical Information Distribution System
JTW	Joint Targeting Workstation
J-UCAS	Joint Unmanned Combat Air System
LAM	Limpet Assembly Modular
LAR	Launch Acceptability Region
LEEFI	Low-Energy EFI
LES	Laser Evaluator System
LGB	laser guided bomb
LGTR	laser-guided training round
LISARDS	Library Information Search and Retrieval Data System
LOGIR	Low-Cost Guided Imaging Rocket
M&S	modeling and simulation
MAC	metal-augmented-charge
MAD	Marine Aviation Detachment
MAD	mass-air-delivery
MAG	Marine Air Group
MAGTAF	Marine Air-Ground Task Force
MALD	Miniature Air-Launched Decoy
MALI	Miniature Air-Launched Interceptor
MALS	Marine Air Logistics Squadron
MANPADS	man portable air defense system
MANTECH	Manufacturing Technology

MARS	Microwave Attitude Reference System
MARS	Missile-All-Up-Round Simulator
MAT	Missile Assist Team
MC02	Millennium Challenge 2002
MCBH	Marine Corps Base Hawaii
MDA	Missile Defense Agency
MDD	maintenance date due
MDF	Mission Data File
MEMS	micro electro-mechanical systems
MER	Mars Exploration Rover
MESA	Missile Engagement Simulation Arena
METOC	Meteorology and Oceanography
MGRS	Military Grid Reference System
MIC	metastable interstitial composite
MIDS	Multifunctional Information Distribution System
MIO	Maritime Intercept Operation
MIRV	multiple independently targetable reentry vehicle
Mk	Mark (DOD designations)
MMPT	Multi-Mission Propulsion Technology
MOCS	Multi-lateration Operations Control System
MOTT	Mobile Ordnance Training Team
MOTU	Mobile Optical Tracking Unit
MPI	Missile Presentencing Inspection
MPM	mission planning module
MRLG	monolithic ring laser gyro
MS	Measures System
MSI	Missile Sentencing Inspection
MSL	Mars Science Laboratory
MSL	mean sea level
MSS	Military Sensor Symposia
MST	Mobile Ship Target
MTI	moving target indicator
NACES	Navy Aircrew Common Ejection Seat
NAMTC	Naval Air Missile Test Center
NAS	Naval Air Station
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NAVAIR	Naval Air Systems Command
NAVSEA	Naval Sea Systems Command
NAVSOC	Naval Satellite Operations Center
NAWCAD	Naval Air Warfare Center Aircraft Division
NAWCWD	Naval Air Warfare Center Weapons Division
NAWS	Naval Air Weapons Station
NCA	Navy Combat Archer
NCW	Network Centric Warfare
NELB	Navy Energetics Leadership Board
NERV	Nuclear Emulsion Recovery Vehicle
NHMF	Non-Toxic Hypergolic Miscible Fuel
NLOP	Nonlinear Optical Polymer
nm	nanometer
NMC	Naval Missile Center
NNSS	Navy Navigational Satellite System
NOL	Naval Ordnance Laboratory
NOTS	Naval Ordnance Test Station
NPTR	National Parachute Test Range
NRO	National Reconnaissance Office
NSA	National Security Agency
NSAP	Navy Science Assistance Program
NSAWC	Naval Strike and Air Warfare Command
NSWC	Naval Surface Warfare Center
NTC	Naval Training Center
NTSB	National Transportation Safety Board
NWC	Naval Weapons Center
NWTS	Naval Weapons Test Squadron
OEF	Operation Enduring Freedom
OFP	operational flight program
OIF	Operation Iraqi Freedom
ONR	Office of Naval Research
OPNAV	Office of the Chief of Naval Operations
OSCAR	Open System Core Avionics Requirement
OT	operational testing
PBX	plastic bonded explosive
PDE	Pulse Detonation Engine
PFPS	Portable Flight-Planning System
PGW	Precision Guided Weapon
PMPT	Paveway Munitions Planning Tool
PMR	Pacific Missile Range
PMRF	Pacific Missile Range Facility
PMTC	Pacific Missile Test Center
PNU	Precision Navigation Upgrade
PRISM	Portable Resource for the Investigation of Suspected MANPADS
PSN	Precision Strike Navigator
PTT	Part Task Trainer
PV	photovoltaic
QB/QF	remotely piloted target aircraft
QDR	Quadrennial Defense Review
QRA	Quick-Reaction Assessment
R&D	research and development
RAAF	Royal Australian Air Force
RAD	rocket-assisted deceleration
RAM	Rolling Airframe Missile
RAMICS	Rapid Airborne Mine Clearance System
RAP	rocket-assisted projectile
RAPEC	rocket-assisted personal ejection catapult
RAT	Rocket-Assisted Torpedo
RAYDAC	Raytheon Digital Computer
RCCM	Radar Calibration Collection Module
RDT&E	research, development, test, and evaluation
REAC	Reeves Electronic Analog Computer
REO	Raymond Engineering Operations
RF	radio frequency
RFI	ready-for-issue
RIMPAC	Rim of the Pacific
RITA	Rapid Imagery Transmission to Aircraft
RMTF	Ready Missile Test Facility
RPG	rocket-propelled grenade
RPT	rapid precision targeting
RPTS	rapid precision targeting system
RPV	Remote Piloted Vehicle
RRL	Radar Reflectivity Laboratory
RTMPS	Real Time Mission Planning System
RTR	real-time radioscopy
RWR	radar warning receiver
S-	anti-submarine
S&T	science and technology
S-A	safety and arming
SAG	Strategic Analysis Group
SAM	surface-to-air missile
SAR	synthetic aperture radar
SBA	simulation based acquisition
SCORE	Southern California Offshore Range
SCS	software configuration set
SCS	system configuration set
SDD	system development and demonstration
SDTS	Self-Defense Test Ship
SEAD	suppression of enemy air defense
SEAL	Sea-Air-Land [team]
SEAWARS	Seawater-Activated Release System
SEC	Support Equipment Change
SECAD	Survivable Engine Control Algorithm Development
SEI	Software Engineering Institute
SEPTAR	seaborne powered target
SFWSL	Strike Fighter Weapons School Atlantic
SFWSP	Strike Fighter Weapons School Pacific
SGI	Silicon Graphics, Inc.
SHARP	Shared Reconnaissance Pod
SIP	Satellite Interceptor Program

SIPRNET	Secret Internet Protocol Network
SLAM	Standoff Land-Attack Missile
SLAM-ER	Standoff Land-Attack Missile–Expanded Response
SLBM	submarine-launched ballistic missile
SLU	surface-launched unit
SM	Standard Missile
SMAU	Stop Motion Aimpoint Update
SNI	San Nicolas Island
SNORT	Supersonic Naval Ordnance Research Track [facility]
SOB	Shrike-On-Board
SPEX	Simple Passive Extinguisher
SPIL	signal-processor-in-the-loop
SPO	System Program Office
SSA	Software Support Activity
SSBR	spin-stabilized bombardment rocket
STG	Synthetic Target Generator
STIC	System Test Integration Center
STM	Supersonic Tactical Missile
STWC	Strike Warfare Command Center
SWARMEX	small-boat-attack exercise
SW-CMM	Software Capability Maturity Model
SWTR	Shallow Water Tracking Range
T&E	test and evaluation
TACAIR	tactical aircraft
TACMAN	Tactical Manual
TACTOM	Tactical Tomahawk
TADIL	Tactical Digital Information Link
TADIRCM	Tactical Aircraft Directable Infrared Countermeasures
TALD	tactical air launched decoy
TAMPS	Tactical Aircraft Mission Planning System
TBM	Theater Ballistic Missile
TBMD	Theater Ballistic Missile Defense
TDD	target-detecting device
TDM	Tactical Dissemination Module
TERCOM	Terrain Contour Matching
TERPES	Tactical Electronic Reconnaissance Processing and Evaluation System
TIMS	Tomahawk In-Flight Missile Simulator
TJA	Thermo Jarrell Ash Corporation
TMD	Theater Missile Defense
TRANSPAC	North Pacific Ocean Monitoring for Climate Research Program
TSPI	time, space, position information
T-SPIL	Threat Signal Processor in the Loop [facility]
TSS	time sensitive strike
TTC	tape transport cartridge
TTP	tactics, techniques, and procedures
TTWCS	Tactical Tomahawk Weapons Control System
TVC	thrust vector control
U.K.	United Kingdom
UAV	unmanned aerial vehicle
UCARS	Unmanned Common Automatic Recovery System
UCAV	unmanned combat air vehicle
UCAV-N	Naval unmanned combat air vehicle
UDF	User Data File
UEU	universal exciter upgrade
UHF	ultra-high-frequency
U.S.	United States
USJFCOM	United States Joint Forces Command
USMC	United States Marine Corps
USN	United States Navy
VA	Medium Attack Squadron
VAL	Variable-Angle Launcher
VBSS	Visit, Board, Search, and Seize
VF	Fighter Squadron
VFA	Strike Fighter Squadron
VFT	virtual flight testing
VLA	Vertical Launch ASROC
VLAP	Vietnam Laboratory Assistance Program
VLSI	very large-scale integration
VMC	visual meteorological conditions
VMR	Virtual Missile Range
VP	Navy Patrol Squadron
VPF	Virtual Prototyping Facility
VSS	vertical-seeking subsystem
VTUAV	vertical take-off and landing unmanned aerial vehicle
VX-	Air Development Squadron
WADS	Western Air Defense Sector
WD	Weapons Division
WEO	Weapons Engagement Office
WEPTAC	Weapons and Tactics Analysis Center
WMD	weapons of mass destruction
WRC	Warfighter Response Center
WSL	Weapons Survivability Laboratory
WSSA	Weapon System Support Activity
WTI	Weapons Tactics Instruction
WWII	World War II
X-	unmanned combat air vehicle

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Note: All previously published (publicly released) material is referenced below. However, many references do not appear on this list since DOD personnel data (reference sources) are restricted to government agencies and their contractors.

Government and DOD contractors. Submit reference requests to wallace.martin@navy.mil.
Other requests. Submit to doris.lance@navy.mil.

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JOINT ACTIVITIES/PARTNERSHIPS

Teamwork is the cornerstone of NAVAIR's success. Each and every activity that China Lake and Point Mugu participate in—every test event, training mission, and laboratory experiment—is a team effort. Teamwork binds together the network of highly trained scientific, technical, and administrative personnel (military, civilian, and contractor) who carry out the NAVAIR mission.

DOD Military Branches

Air Force
- 419th Flight Test Squadron, Edwards AFB, CA
- 513th Fighter Squadron, Nellis AFB, NV
- Arnold Engineering Development Center (AEDC)
- Edwards AFB, CA
- Eglin AFB, FL
- Hickam AFB, HI
- Hill AFB, UT
- McChord AFT, WA
- Vandenberg AFB, CA
- Warner-Robbins AFB, GA
- Wright-Patterson AFB, OH

Army
- Corps of Engineers
- McAlester Army Ammunition Plant (MCAAP), OK
- Naval Training Center (NTC), Fort Irwin, CA
- Redstone Arsenal, AL

Coast Guard

Marine Corps
- Fleet Weapons Support Team (FWST)
- HMLA-267
- Marine Air Group (MAG)-11
- Marine Air Group (MAG)-31
- Marine Air Logistics Squadron (MALS) –11
- Marine Air Logistics Squadron (MALS) –31
- Marine Air Logistics Squadron (MALS) –39
- Marine Aircraft Wing (3rd MAW)
- Marine Aviation Detachment (MAD)

Navy
- Air Test and Evaluation Squadron Nine (VX-9)
- Bureau of Ordnance (BuOrd)
- Naval Air Station (NAS) Lemoore, CA
- Naval Air Station (NAS) Miramar, CA
- Naval Base Ventura County, CA
- Naval Energetics Leadership Board (NELB)
- Naval Network and Space Operations Command (NAVSOC)
- Naval Ordnance Laboratory (NOL) Corona, CA
- Naval Strike and Air Warfare Center (NSAWC)
- Naval Surface Warfare Center (NSWC) Crane, IN
- Naval Surface Warfare Center (NSWC) Dahlgren, VA
- Naval Surface Warfare Center (NSWC) Fallon, NV
- Naval Surface Warfare Center (NSWC) Indian Head, MD
- Naval Surface Warfare Center (NSWC) Port Hueneme, CA
- NAVSEA
- Navy Integrated Call Center, Norfolk, VA
- Navy Navigational Satellite System (NNSS)/TRANSIT
- Navy Science Assistance Program (NSAP)
- Office of Naval Research (ONR)
- Pacific Fleet Operating Forces
- Strike Fighter Weapons School Atlantic (SFWSL)
- Strike Fighter Weapons School Pacific (SFWSP)
- Third Fleet
- VA-83
- VA-145
- VF-31
- VF-102
- VF-213
- VFA-41
- VFA-115
- VFA-146
- VFA-147
- VP
- VP-9
- VP-10
- VP-16
- VP-46

DOD Military Joint Activities

- DOD Soldering School
- Joint Army-Navy-NASA-Air Force Interagency Propulsion Committee (JANNAF)
- Joint Combined Interoperability Evaluation Team (JCIET)
- Joint Fleet Exercise (JTFEX)
- Joint Forces Command (JFCOM)
- Joint Munitions Effectiveness Manual (JMEM)
- Joint Munitions Planning System (JMPS)
- Joint National Training Center (JNTC)
- Joint Services Air Defense Lethality Team (JSADLT)
- Joint System Support Activity (JSSA)
- Joint Tactical Information Distribution System (JTIDS)
- Joint Technical Coordinating Group for Aircraft Survivability (JTCG/AS)
- Joint Technical Coordinating Group for Munitions Effectiveness (JTCG/ME)
- Joint Test and Evaluation (JT&E)
- Joint Tunnel Warfare Activities
- Joint Unmanned Combat Air System (J-UCAS)
- Warfighter Response Center (WRC)

DOD NAVAIR Partners

- Aircraft Division (AD)
- Cherry Point (North Carolina)
- Depots
- Jacksonville (Florida)
- Lakehurst (New Jersey)
- North Island (San Diego, CA)
- Orlando (Florida)
- Patuxent River (Pax)

DOD Joint Aircraft

- Joint Strike Fighter (JSF)

DOD Joint Weapons (Formal Joint Acquisition Programs)

- Joint Air-to-Surface Standoff Missile (JASSM)
- Joint Direct Attack Munition (JDAM)
- Joint Standoff Weapon (JSOW)

DOD Joint Weapons (Interservice Cooperative Ventures)

- AMRAAM
- ASROC/VLA
- Atomic Weapons
- FAE
- Fleet Ballistic Missiles
- Gator
- General Purpose Bombs
- HARM
- Harpoon, SLAM, SLAM-ER
- Hellfire
- Laser Guided bombs
- Maverick
- Phalanx
- Phoenix
- RAM
- Rockets
- Shrike
- Sidewinder
- Skipper
- Sparrow, SeaSparrow, ESSM
- Standard Missile
- Tomahawk
- Walleye

DOD Joint Weapon Systems

- Joint Helmet Mounted Cueing System (JHMCS)
- Joint Improved Mk 82 Series (JIMS) Bomb Fin Project

- Joint Targeting Workstation (JTW)

DOD Organizations (Joint Activities)
- Advanced Research Projects Agency (ARPA)
- Atlantic Fleet Weapons Test Facility (AFWTF)
- Defense Advanced Research Projects Agency (DARPA)
- Defense Threat Reduction Agency (DTRA)
- Joint Forces Command (JFCOM)
- Missile Defense Agency (MDA)
- National Air Intelligence Center (NAIC)
- National Imagery and Mapping Agency (NIMA)
- National Reconnaissance Office (NRO)
- National Transportation Safety Board (NTSB)
- Special Forces
- White Sands Missile Range, NM

DOD Partners (International)
- Australia
- Bahrain
- Canada
- Egypt
- England
- Finland
- Foreign Military Sales (FMS)
- Greece
- Israel
- Italy
- Japan
- Netherlands
- Spain
- Switzerland

International Forums
- Australia
- Foreign Comparative Test Program
- Germany
- Great Britain
- Military Sensor Symposia (MSS)
- National Fire Control Symposium
- NATO countries
- New Zealand
- Technical Cooperation Program Affairs

Technical Support
- Foreign and International IM Support
- Germany
- Italy
- Netherlands

Testing and Training
- Australia
- Canada
- Croatia
- Denmark
- Egypt
- France
- Germany
- Great Britain
- Israel
- Italy
- Japan
- Korea
- North Atlantic Treaty Organization (NATO)
- Norway
- Spain
- Switzerland
- Thailand

Weapons and Systems
- England
- Germany
- Great Britain
- Italy
- Korea
- NATO Countries
- Netherlands
- Norway

Weapon Integration
- Finland
- Germany
- Great Britain
- Italy
- Spain

Educational Institutions (Joint Activities)
- California Institute of Technology (Caltech)
- California State Polytechnic University, Pamona, CA
- Carnegie Mellon University
- Cornell University
- New Mexico Institute of Technology
- San Diego State University
- University of California Los Angeles (UCLA)

Educational Partnership Agreements (EPAs)
- California State Polytechnic University, Pomona, CA
- New Mexico Institute of Technology

Government Agencies (Joint Activities)
- American Institute of Aeronautics and Astronautics (AIAA)
- Atomic Energy Commission (AEC)
- Bureau of Land Management (BLM)
- Federal Aviation Administration (FAA)
- Federal Bureau of Investigation (FBI)
- Federal Laboratory Consortium (FLC)
- Fire Departments
- Law Enforcement Agencies
- NASA
- NASA Glenn
- National Institute of Health (NIH)
- National Science Foundation (NSF)
- National Security Agency (NSA)
- National Transportation Safety Board (NTSB)

Industry Partners

Commercial Service Agreement (CSA)
- BAE
- Boeing
- Lockheed Martin
- Northrop Grumman
- Raytheon

Cooperative Research and Development Agreement (CRADA)
- Apple Computer
- Comarco, Inc.
- Military and Commercial Industries
- Raymond Engineering Operations (REO)
- San Diego State University
- Thermo Jarrell Ash Corporation (TJA)
- Thiokol Propulsion

Major Industry Customers
- Boeing
- British Aerospace Systems (BAE)
- General Atomics
- Lockheed Martin
- Northrop Grumman
- Raytheon

Special Joint Projects With Industry
- Automobile Manufacturers
- CACT CO
- Elcan
- Emergency Product Manufacturers
- General Dynamics
- Goodyear Aerospace
- Hi-Shear Technologies
- Hughes
- Jet Propulsion Laboratory (JPL)
- Kearfott Guidance and Navigation Corporation
- Lawrence Livermore Laboratory
- Los Alamos National Laboratory, NM
- LTV Aerospace
- Mayo Clinic
- McDonnell Douglas
- Microsoft
- Southern California Edison (SCE)
- Sports Broadcasting Industry
- Texas Instruments (TI)

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NAVAIR **Weapons Division** China Lake, CA · Point Mugu, CA

Who We Are – What We Do

Mission. To provide our armed forces with effective and affordable integrated warfare systems and life-cycle support to ensure battlespace dominance.

- Perform research, development, test, and evaluation (RDT&E), logistics, and in-service support for guided missiles, free-fall weapons, targets, support equipment, crew systems, and electronic warfare.
- Integrate weapons and avionics on tactical aircraft.
- Operate the Navy's western land and sea range test and evaluation complex.
- Develop and apply new technology to ensure battlespace dominance.

- Free world's leader in RDT&E of guided missiles, advanced weapons, and weapon systems. Proven through 50 years of unparalleled products.
- World leader in complex weapon systems and software integration.
- World leader in energetic materials and subsystems.
- Developed the Sidewinder missile—the world's premiere dog-fight weapon. Sold to 31 countries.
- Unique world class facilities and test ranges for weapon system solutions for the warfighter.
- Finest weather in the world for testing. 360 clear days per year.

Enormous unencroached land, sea, and airspace:

- 1.1 million acres (larger than the state of Rhode Island)
- 36,000 square miles of sea range off the Southern California coast, including San Nicolas Island.
- R-2508 restricted airspace encompasses 12% of California's total airspace. Jointly managed with Edwards AFB and Fort Irwin.
- Few areas in the world offer such a wide variety of geographical features in close proximity—mountains, ocean, deep water ports, protected islands, deserts, canyons, and forests.

Major Products and Services

Missiles and Free-Fall Weapons

AMRAAM, HARM, Harpoon, Hellfire, JDAM, JSOW, Penguin, Phoenix, RAM, Sidewinder, SeaSparrow, SLAM, SLAM-ER, Standard Missile, Tomahawk, VLA.

Weapon System Integration

All Navy and Marine Corps tactical aircraft, including the F/A-18, F-14, AV-8B, EA-6B, EP-3E, AH-1, JSF, and the F-22 (Air Force).

Electronic Warfare

AN/AAR-47 Warning System; AN/ALE-29, -39, -47, -50 Countermeasures Systems; AN/ALR-66, -67 Warning Systems; Infrared Countermeasures; Integrated Defense Electronic Countermeasures.

Research, Development, Test, and Evaluation

- Engineering/logistics for tactical missiles and free-fall weapons
- T&E of weapons, weapon components, and integrated weapons systems in realistic environments
- National Parachute Test Range
- Full-scale joint-live-fire survivability testing
- Explosives and propellants RDT&E from laboratory samples up to 500,000 pounds
- Network Centric Warfare; interoperability
- Modeling and simulation
- Basic and applied research, science, and technology
- Full-scale and sub-scale targets

Fleet Preparedness Training

Fleet training and tactics development, including major exercises on the Sea Range, Land Range, Superior Valley, and Electronic Combat Range.

Scope of Operations (FY03)

Revenue $1.01 billion
Contracts (all supplies and services) $421,000,000
Personnel (As of March 1, 2004)
- Civil Service: 4,251
- Military: 507
- Contractors: 2,224
- Total: 6,982

Size
- Number of acres: 1.1 million
- Square miles of restricted airspace over land: 17,000
- Square miles of restricted airspace over sea: 36,000
  - Test area expandable to: 125,000

Facilities
- Buildings: >3,000
- Major facilities: 40. Airfields: 2.
- Plant replacement value: $2.8 billion

Annual Test Events 3,100
Training Sorties 1,400
Major Training Exercises 30

Partnering Opportunities. DoD, other agencies, academia, and industry. Cooperative Research and Development Agreements, Commercial Service Agreements, Navy Potential Contractor Program and Patent License Agreements.

Customers (Partial List)

Major Programs. F/A-18, AV-8B, F-14, Sidewinder, HARM, EA-6B, AH-1, TACAIR EW, Standard Missile, Tomahawk, JSOW, EP-3E, Harpoon, SLAM, RAM, JDAM, TAMPS, JMPS, AMRAAM, RAM, SLAM-ER, Trident, Sparrow, Patriot, F-22, V-22, ESSM, Hellfire, JASSM, NACES, T-45, Fleet Battle Experiments, Naval Fires Network, VLA, GCCS-M, JSIPS-N.

Government. ONR, NAVSEA, SPAWAR, Special Forces, USAF, Army, NASA, FBI, FAA, Dept. of Transportation, NRO, NIMA, DARPA, DTRA, NTSB, Missile Defense Agency.

Foreign. Japan, Australia, Canada, Germany, Israel, Spain, Switzerland, Taiwan, UK, France, Norway, Italy.

Major Industry. Boeing, Lockheed Martin, Raytheon, Northrop-Grumman, General Atomics, BAE Systems.

Looking to the Future
- Network Centric Warfare
- Energetics
- High Speed Weapons
- Unmanned Aviation
- Homeland Defense – Counter Terrorism

WEAPONS DIVISION WEB SITES

Weapons Division homepage (http://www.nawcwd.navy.mil/)
- This site averages between 80,000 to 100,000 hits per day worldwide
- Frequently used WD sites (http://www.nawcwd.navy.mil/sites.html)

NAVAIR site (http://www.navair.navy.mil/)

Naval Air Systems Command

NAVAIR delivers weapon systems to warriors for Navy and Marine Corps missions. Our products and services include fixed and rotary wing aircraft, avionics, air- and surface-launched weapons, electronic warfare systems, cruise missiles, unmanned aerial vehicles, launch and arresting gear, and training systems. NAVAIR provides total life cycle support of our products: research, design, development, and engineering; acquisition; test and evaluation; repair and modification; and in-service engineering and logistics support.

NAVAIR encompasses eight sites across the country. The Weapons Division is located at China Lake and Point Mugu, California. NAVAIR Aircraft Division has sites at Patuxent River Maryland; Lakehurst, New Jersey; and Orlando, Florida. NAVAIR depots are located at North Island, California; Jacksonville, Florida; and Cherry Point, North Carolina.

NAVAIR has approximately 32,000 military and civilian employees; manages approximately 150 acquisition programs; and maintains more than 4,100 aircraft in active inventory, including 96 individual type/model/series. Principal customers include the operating forces of the Navy and Marine Corps, joint programs of the U.S. Department of Defense, other activities of the U.S. Armed Forces, and foreign allies.

NAVAIR is comprised of six organizations working as a fully integrated team: Naval Air Systems Command (NAVAIR); Naval Inventory Control Point (NAVICP); Program Executive Office, Air Anti-Submarine Warfare, Assault, and Special Mission Programs (PEO(A)); Program Executive Office, Tactical Aircraft Programs (PEO(T)); Program Executive Office, Strike Weapons and Unmanned Aviation (PEO(W)); and Program Executive Office, Joint Strike Fighter (PEO(JSF)).

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