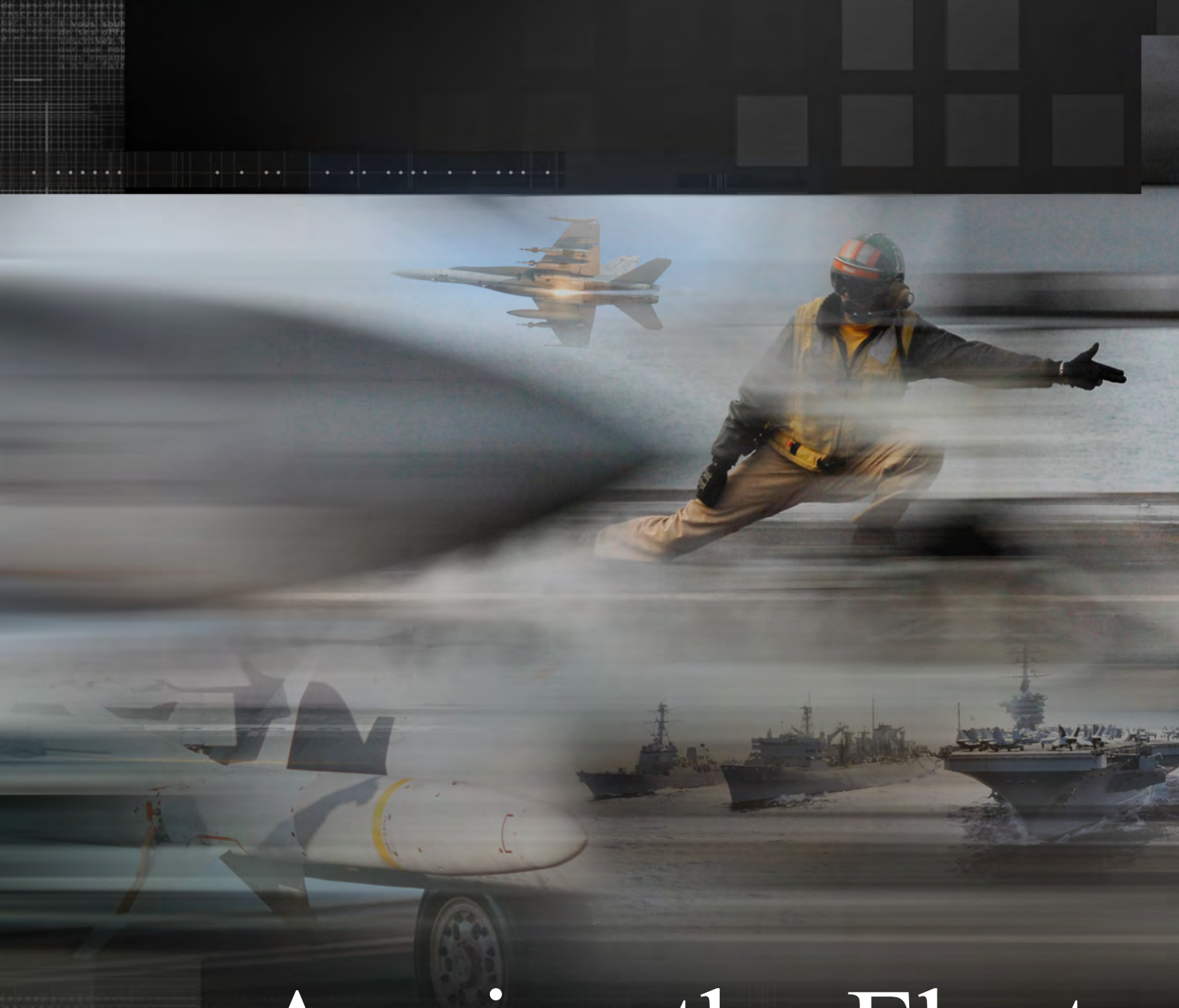

Arming the Fleet

THIRD EDITION

1943 - 2011

Providing Our Warfighters the Decisive Advantage

Naval Air Warfare Center Weapons Division
China Lake and Point Mugu, California

AUTHENTICATED
U.S. GOVERNMENT
INFORMATION
GPO

Naval Air Systems Command

Sailors and Marines Armed with Confidence…

Because we develop, deliver, and sustain aircraft, weapons, and systems—on time, on cost, with proven capability and reliability—so they succeed in every mission and return safely home.

Foreword

In June 1963, in front of more than 60,000 people who crowded the Point Mugu tarmac, President John F. Kennedy said, "I go back to Washington with the feeling of renewed pride in being an American and renewed confidence in being a citizen of the greatest republic on earth." A day later, President Kennedy flew to China Lake for a brief tour, where thousands also came to see their president. "I cannot think of a prouder statement when asked what our occupation may be than to say 'I serve the United States of America,'" stated the president. His words touched the hearts of all those in attendance.

Through the years, naval projects and missions have changed, but pride in serving this country has not. The people employed at China Lake and Point Mugu are reminded of the history within the walls of their many laboratories. Through the hallways, echoes of the past precede the sounds of the present, telling us to build on the past's lessons and trials, failures and successes.

Nothing should remain stagnant, and, in today's world of uncertainty and crisis, the military is one area where we must continue to advance to protect our country and give our warfighters a decisive advantage over our enemies.

The Naval Air Warfare Center Weapons Division (NAWCWD) has made countless contributions to our warfighters. This publication highlights many of them—describing our support in all major military conflicts beginning with World War II, discussing many weapons developed or supported, and illustrating the many technologies invented. This publication could not possibly include every project in which NAWCWD has been involved throughout its illustrious history. Therefore, only its most noteworthy achievements have been cited.

Regardless of the task or mission, our workforce is proud to say, "I serve the United States of America."

Rear Admiral Mathias W. Winter
Commander
NAWCWD

Scott M. O'Neil
Executive Director
Research and Engineering
NAWCWD

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NAWCWD provides direct fleet support in multiple areas shown in the table of contents. In addition, NAWCWD is also heavily engaged in other work involving energetics, weapons/platform integration, system-of-systems integration, and survivability/vulnerability/lethality. Examples of programs and projects are described throughout this publication.

“I cannot think of a prouder statement when asked what our occupation may be than to say ‘I serve the United States of America.’”

—John F. Kennedy, President of the United States

NAVAIR Overview

The Naval Air Systems Command (NAVAIR) delivers weapon systems to Sailors and Marines for Navy and Marine Corps missions. Products and services include fixed- and rotary-wing aircraft, avionics, air- and surface-launched weapons, electronic warfare (EW) systems, cruise missiles, unmanned aerial vehicles (UAVs), 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 Naval Air Warfare Center Weapons Division (NAWCWD) 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 (T&E); 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 NAWCWD, 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 U.S. military crisis since World War II, RDT&E efforts at China Lake and Point Mugu have played a significant role—developing and testing weapons and systems that work.

NAWCWD Vision, Mission, and Goals

The **NAWCWD Vision** is *to be the leader providing innovative, integrated, and dominant warfighting effects for our naval, joint, and coalition forces***.** The **NAWCWD Mission** is *to execute full-spectrum weapons and warfare systems research, development, acquisition, test, and evaluation (RDAT&E)*. The Mission is enabled through recruiting, developing, and retaining a relevant, qualified workforce; developing, maintaining, and operating unique cross-domain land, air, and sea ranges and laboratory capabilities; and partnering with industry, academia, Department of Defense (DoD), and the international community. In the performance of the Mission, stewardship of natural resources and the environment is a paramount duty.

NAWCWD is fully engaged in the execution and support of work across the breadth of RDAT&E. A major goal is to provide naval, joint, and coalition partners with products and services on time and on budget. The Command supports a wide variety of customers and provides substantial resources to continue developing, delivering, and sustaining affordable, quality products and services.

Pursuit of key technology-driven emerging capabilities is another major goal. Technology, innovation, research, and development are the cornerstones that allow NAWCWD to rapidly counter evolving threats with novel warfighter capabilities. Substantial investment and involvement in independent and applied research and core science and technology networks keep NAWCWD at the forefront of relevant technologies and its application to the Mission.

NAWCWD "Firsts"

NAWCWD provides direct Fleet support for naval aviation and is recognized for a number of significant firsts. NAWCWD 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, NAWCWD is occasionally called upon by the National Aeronautics and Space Administration (NASA) to lend expertise to projects of national importance. Lessons learned from joint projects help NAWCWD find solutions to naval aviation problems. China Lake and Point Mugu are recognized for several space-related and earlier undersea firsts.

NAWCWD—Making History

Weapons Firsts…

- Fire-and-forget guided missile under 6 pounds—Spike
- Air-to-air guided missile used in combat—Sidewinder
- Successful anti-radiation missile (ARM)—Shrike
- Air-to-surface precision-guided missile—Walleye
- Fire-and-forget precision-guided imaging infrared (IR) 2.75-inch rocket—Low-Cost Guided Imaging Rocket (LOGIR)
- Low collateral damage precision-guided munition (PGM) warhead, 85% less explosive, same mass properties—Low Collateral Damage Bomb (LCDB, also known as LOCO)
- Feasibility studies, concept development, and early testing—Polaris missile
- Nonnuclear components and testing—atomic bomb
- Plastic-bonded explosives
- U.S. aircraft rockets
- "No-smoke" missiles
- Controlled fragmentation Pearson Notch, still the standard method for warhead case controlled fragmentation
- Metal augmentation charge (MAC) enhanced thermobaric warhead—Hellfire AGM-114N
- U.S. Navy's premier hard target penetration weapon—BLU-116/B
- Cast ductile iron warheads—a family of Mk 80 series weapons
- Cast iron weapon store qualified for flight on Air Force and Navy aircraft
- Heavy-wall practice bomb

Technology Firsts…

- Chemiluminescent light sticks
- Stop-action video
- Automatic air bag sensors
- Ground-based passive IR system to track and autonomously declare antiaircraft missiles, thus allowing time to employ precision countermeasures—distributed ground-based threat detection system (DGTDS)
- Radar for automatic discrimination of submarine periscopes in high-clutter environments with low probability of false alarms—automatic radar periscope detection and discrimination (ARPDD)
- Reprogrammable self-protection jammer
- Real-time night display of targets
- Real-time X-ray video system to see inside a rocket motor while being fired
- Subject search made by a digital computer
- Body-scanning technology—logarithmic amplifiers
- Active optical and proximity fuze technologies

Testing Firsts…

- Unmanned aircraft to release a Global Positioning System (GPS)-guided weapon
- Pegasus X-47A and Fire Scout RQ-8 UAV flights
- Hellfire missile launch from Sky Warrior UAV
- UAV search and rescue support with Predator B
- Tactical Tomahawk launch with live warhead; first launch from a British submarine
- Standard Missile-3 sea-based ballistic missile intercept
- Standoff Land Attack Missile (SLAM) firing
- Air-to-air "six-on-six" (missiles launched/targets killed)—Phoenix
- Plane and crew to land at the South Pole—VXE-6
- U.S. kill of an airborne target by an air-to-air guided missile—Sparrow
- Contact hit against an airborne target by a surface-to-air guided missile—Lark

Space and Undersea Firsts…

- Lunar lander and Mars lander subsystems
- U.S. satellite launch—NOTSNIK
- Antisatellite weapons demonstration
- Technology allowing images from space to be sent back to Earth
- U.S. manned submersible to descend 2,000 feet—Deep Jeep

NAWCWD, How It All Began

Before China Lake and Point Mugu merged to form NAWCWD, they were separate naval installations, each with its own storied history and reputation.

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 facility is located 150 miles northeast of Los Angeles in the remote western edge of California's Mojave Desert. The formal mission statement for NOTS in 1943 identified "research, development, and test of weapons" as the Station's primary purpose, which remains its mission today. The first weapons included rockets, such as Mighty Mouse and Zuni, and, because of its remote location, China Lake was also part of the team developing the first atomic weapons.

Also, in 1946, the naval presence at Point Mugu began when Seabees from Port Hueneme put down a Marsden mat runway as the first airstrip in that area. The Navy recognized the importance of a large sea range for T&E functions only 65 miles northwest of Los Angeles, so Point Mugu became the Naval Air Missile Test Center (NAMTC). The NAMTC, which was the U.S. Navy's first instrumented missile test sea range, developed and tested missiles and drones, including the Gorgon, Gargoyle, Lark, and Little Joe.

After World War II, both NOTS and NAMTC excelled in their support of the Warfighter. Scientists and engineers at both locations continued to develop new and innovative weapons. One example is the AIM-9 Sidewinder air-to-air missile, which originated at China Lake and became the world's most used and most copied air-to-air missile.

As the bases added new weapons and technologies to their list of accomplishments, they also continued to evolve as naval installations. For example, in 1958, the Pacific Missile Range (PMR) at Point Mugu was established. By 1959, NAMTC was renamed the Naval Missile Center (NMC). In 1971, Point Mugu, which was already home to the F-14 Tomcat System Integration Test

Station, became host to the Software Support Activity for the Tomcat. Four years later, because the sea ranges were test locations for such weapons as the Harpoon, Tomahawk, Trident, and Standard Missile, the Navy merged the PMR and the NMC into the Pacific Missile Test Center (PMTC). China Lake was also evolving with its warfighter contributions and growing reputation of excellence. By 1967, it was combined with the Naval Ordnance Laboratory at Corona to form the newly created Naval Weapons Center (NWC). In 1979, the National Parachute Test Range at El Centro, California, merged with NWC, further increasing NWC's functionality.

The Navy then continued its efforts to streamline naval functions and consolidate duplicated tasking and research, as well as to broaden the communication between RDT&E facilities. To this end, by 1992, the PMTC, NWC China Lake, and the NAVAIR units at White Sands and Albuquerque, New Mexico, had merged to form NAWCWD. In 2001, the White Sands detachment was transferred to the Naval Sea Systems Command (NAVSEA). NAWCWD is headquartered at China Lake and is a tenant of the Navy Region Southwest, which includes several military bases on the West Coast, such as San Diego; Point Loma; and the Naval Air Station (NAS), Fallon, Nevada.

NAWCWD became one of the largest and most diverse test ranges in the world, with a wide variety of features—mountains, ocean, deep-water ports, protected islands, deserts, canyons, and forests—all close to one another and all highly instrumented. NAWCWD is a billion-dollar-per-year operation, with more than 6,500 employees and 40 major facilities, many of which are not duplicated anywhere else in the world. The installation hosts thousands of official visitors annually, ranging from joint services, allies, and official delegates.

As the Warfighter moves into the future, NAWCWD is leading the way by continuing to develop state-of-the-art weapons and technologies. With its new laboratories and facilities, which will provide new and exciting capabilities, NAWCWD has an exceedingly bright future, will continue to grow significantly, and will remain the U.S. military's leading RDT&E facility far into the future.

China Lake and Point Mugu Designated as Historical Aerospace Sites

For more than 75 years, the American Institute of Aeronautics and Astronautics (AIAA) has been the principal technical society devoted to continuing contributions and global leadership in the aerospace profession. The institute has more than 35,000 members, both professionals and students, and conducts many national technical conferences each year and publishes many textbooks, technical journals, and short courses annually. The AIAA Board of Directors established the historic Aerospace Sites Committee in 1999 to recognize and preserve significant contributions made in both aeronautics and astronautics to culture and technology. Advances and discoveries in the aerospace field have significantly affected the lives of people the world over.

AIAA Point Mugu Historic Aerospace Site

On November 14, 2003, the Naval Base Ventura County at Point Mugu was formally named an AIAA historic site. The citation reads as follows:

> Established in 1946 to provide a comprehensive test and evaluation site for tactical missiles, Point Mugu has been instrumental in the development, test, evaluation, and in-service support of systems including Regulus, Sparrow, Phoenix, Bullpup, Harpoon, SLAM, Tomahawk, Standard, and Rolling Airframe Missile. The first missile launch from an operational submarine was also accomplished at Point Mugu.

The institute designation placed this installation in the company of 20 other historic spots, including Kitty Hawk, North Carolina; 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 (AFB), home of legendary test pilots and fledgling astronauts; and the Pasadena plant site where scientists for Aerojet Engineering invented rocket fuel in the 1940s.

AIAA China Lake Historic Aerospace Site

In 2006, China Lake was also chosen an AIAA Historic Aerospace Site, along with the NASA Johnson Space Center, Houston, Texas. The bronze plaque was unveiled by Rear Admiral Walter Skinner at a formal public dedication held at the U.S. Naval Museum of Armament and Technology. The citation reads as follows:

> China Lake is one of the nation's premiere weapons laboratories. Established in 1943, China Lake supports naval aviation and warfighter requirements and will continue to arm the Fleet into the future. The Station conceived and developed rockets during WWII; nonnuclear components for the first atomic bomb; Sidewinder, Shrike, and Walleye missiles; and the Polaris concept. China Lake developed NOTSNIK in 1958 and vital components for the Mars lander in 2004. The Station, a world leader in aircraft–weapons integration, testing, and electronic warfare, developed 75% of the air-launched weapons used during Vietnam and jointly developed 80% of those used during Iraqi Freedom.

As part of the ceremonies, the U.S. Naval Museum of Armament and Technology restored and unveiled two new exhibits, including the Mk IV Fleet version of the Fat Man and the Caleb, the follow-on to NOTSNIK, part of China Lake's early satellite program.

Teamwork

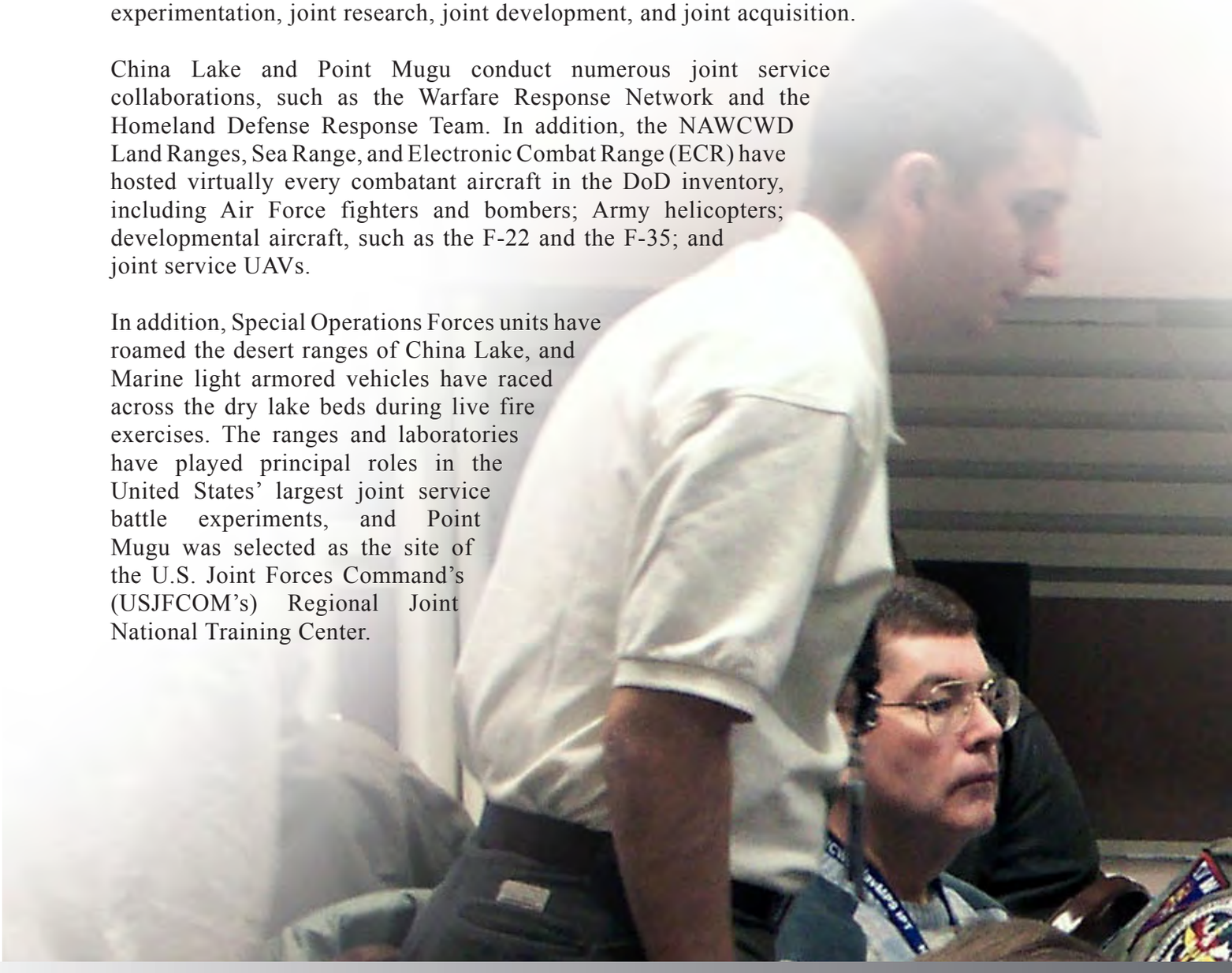
Teamwork is the cornerstone of NAVAIR's success. Every test event, training mission, and laboratory experiment at China Lake and Point Mugu is a team effort. Throughout NAWCWD, more than 4,000 federal employees combine with more than 1,700 defense contractors and 200 military service men and women to form a cohesive team to support the NAVAIR mission. This teamwork binds together the network of highly trained scientific, technical, and administrative personnel.

Joint Services

Teamwork at NAWCWD is not only internal to the Navy but also reaches across service boundaries to the Marine Corps, Army, Air Force, Coast Guard, and Department of Homeland Security. NAVAIR is at the forefront of joint service activity—joint training, joint testing, joint experimentation, joint research, joint development, and joint acquisition.

China Lake and Point Mugu conduct numerous joint service collaborations, such as the Warfare Response Network and the Homeland Defense Response Team. In addition, the NAWCWD Land Ranges, Sea Range, and Electronic Combat Range (ECR) have hosted virtually every combatant aircraft in the DoD inventory, including Air Force fighters and bombers; Army helicopters; developmental aircraft, such as the F-22 and the F-35; and joint service UAVs.

In addition, Special Operations Forces units have roamed the desert ranges of China Lake, and Marine light armored vehicles have raced across the dry lake beds during live fire exercises. The ranges and laboratories have played principal roles in the United States' largest joint service battle experiments, and Point Mugu was selected as the site of the U.S. Joint Forces Command's (USJFCOM's) Regional Joint National Training Center.



International Services

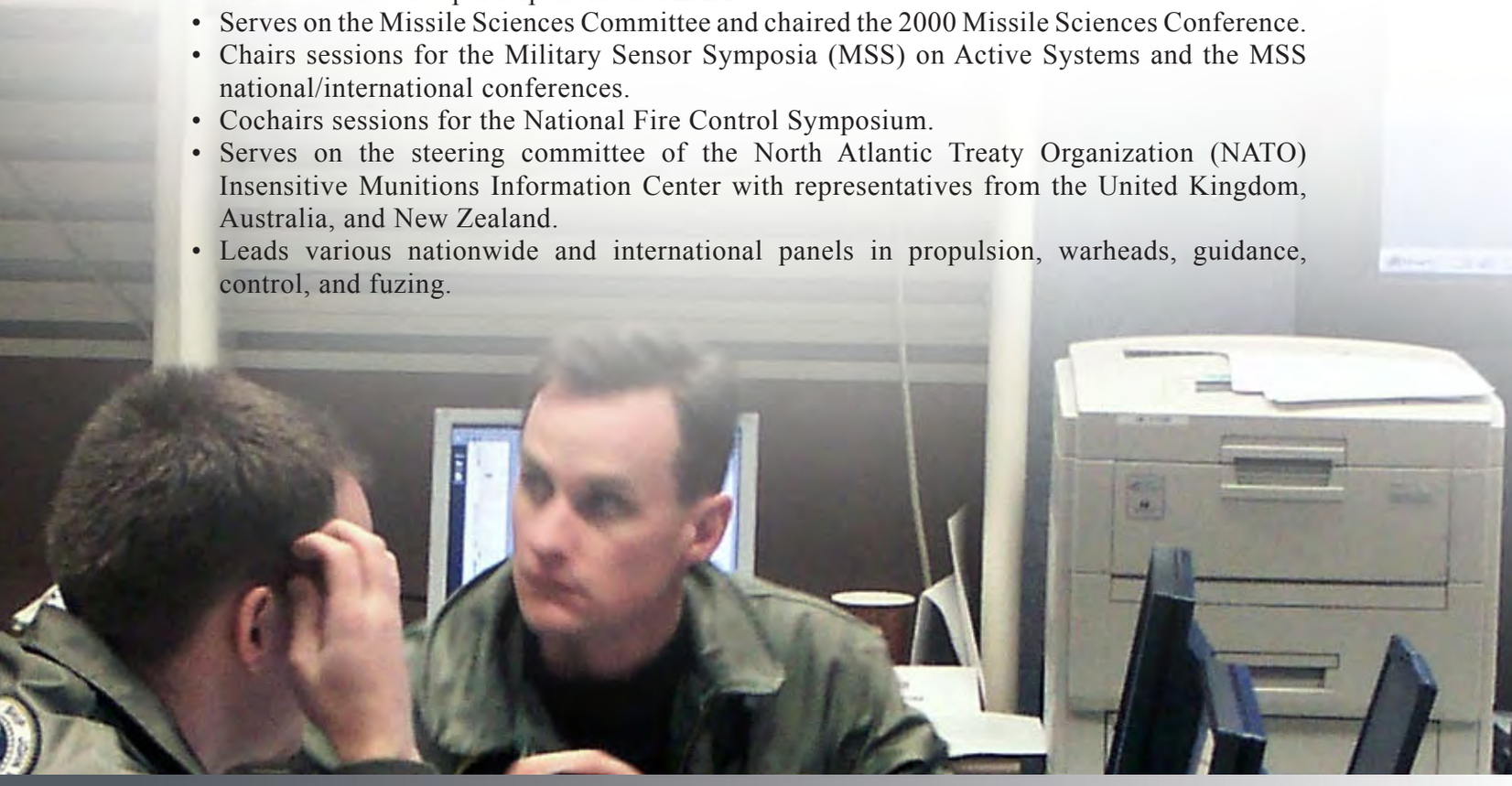
The United States' international allies benefit from the same principles of teamwork. The first Tomahawk firing from a British submarine, for example, took place on the NAWCWD Sea Range. The Japanese Defense Force conducts annual training and missile development exercises on the Sea Range also. The Italian Air Force trains with the High-Speed Anti-Radiation Missile (HARM) on the NAWCWD Land Ranges; the Royal Danish Navy has participated in Evolved SeaSparrow Missile (ESSM) launches on the ranges as well. Many allied countries send representatives to the F/A-18 Advanced Weapons Laboratory (AWL), where NAWCWD provides its expertise in system integration. Several allies have permanent facilities located on NAWCWD, although their access to the ranges and laboratories is restricted and closely monitored.

Many weapons developed by NAWCWD are later sold to U.S. allies. These foreign military sales (FMS) are contingent on the country being authorized to participate and its ability to provide appropriate funding. To maintain its strategic edge, the DoD may sell a weapon's lower variant without current capabilities, if the military deems the current weapon is essential to U.S. national defense. NAWCWD supports FMS customers by providing range support, weapon integration, and training and technical support. [218]

National and International Forums

NAWCWD has historically played a leadership role in many professional societies. For example, NAWCWD representatives are on the Executive Committee of the Joint Army, Navy, NASA, and Air Force (JANNAF) Interagency Propulsion Committee. Other forum participation includes the following. [40] [203]

- Serves as an active participant in the AIAA.
- Serves on the Missile Sciences Committee and chaired the 2000 Missile Sciences Conference.
- Chairs sessions for the Military Sensor Symposia (MSS) on Active Systems and the MSS national/international conferences.
- Cochairs sessions for the National Fire Control Symposium.
- Serves on the steering committee of the North Atlantic Treaty Organization (NATO) Insensitive Munitions Information Center with representatives from the United Kingdom, Australia, and New Zealand.
- Leads various nationwide and international panels in propulsion, warheads, guidance, control, and fuzing.



“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

“Through its entire history, the [Pacific Missile Test] Center has benefitted tremendously from the human side of the equation. In the final analysis, the people have really been the most important part of the evolution and success of the Center.”

—Mr. K. I. Lichti, Technical Director, PMTC, Point Mugu

Military Conflicts—Highlights

Military Conflicts—Highlights

NAWCWD's support of the Warfighter has been an ongoing effort since its establishment during World War II. The contributions made by China Lake and Point Mugu range from direct support in response to immediate Fleet needs to ensuring the Warfighter will have the advantage in future conflicts. Those contributions are innumerable, so trying to provide a comprehensive list is both futile and beyond the scope of this publication. Therefore, what follows is a collection of specific examples designed to illustrate the extent of that effort.

World War II

China Lake's initial role during World War II was in support of the Caltech rocket program. The partnership led to the first air-launched rockets to enter the U.S. inventory. One of those rockets was the 2.75-inch forward-firing aircraft rocket. This rocket remains one of the most fired weapons in history, surpassed only by bullet-type ammunition. [141]

Another early rocket was Holy Moses, a 5.0-inch high-velocity aircraft rocket. Holy Moses is an example of an early China Lake quick-response accomplishment. Tasked with improving the effectiveness of the British 3.0-inch rocket, Caltech and China Lake designed and developed the 5.0-inch rocket in a matter of months. This rocket could penetrate 1.5 inches of armor and 4 feet of concrete. During production, 100 rounds were manufactured and sent abroad every day until 1,400 rounds were delivered. [141]

China Lake also developed the Spin-Stabilized Bombardment Rocket (SSBR) used in ship-to-shore barrages and a rocket-thrown line charge used to clear hazardous landing areas. The land-clearing system was the first of its kind, and the technology involved served as the basis for all future land-clearing systems used by U.S. armed services. [141] [145]

Apart from the rocket work, China Lake also helped to develop the atomic weapon that eventually brought an end to the war. China Lake was tasked with creating the conventional explosives that trigger the nuclear core, testing detonators and fuzes, and dropping inert bombs from B-29 bombers to perfect the procedures and tactics used in delivering an atomic bomb.

Korean War

With the outbreak of war in Korea in 1950, NAWCWD was once again called upon to aid the Warfighter. In its second quick-response effort in as many wars, China Lake built an antitank rocket in response to an urgent need for a weapon that could engage North Korean tanks with what was initially thought to be 13-inch-thick armor plating (North Korean tanks were later confirmed to have 5-inch-thick armor plating). In just under 1 month, China Lake designed, developed, tested, and built a shaped-charge warhead for the 5.0-inch high-velocity aircraft rocket, thereby resulting in the Antitank Aircraft Rocket (ATAR), or Ram, as it was known.

It was also during this time that development began on Sidewinder under the code name Local Project 612. Built almost entirely by Dr. William B. McLean, the Sidewinder prototype was a rocket-propelled bomb with a heat-detecting device in the nose to home in on enemy jet exhaust heat. With a total of nine moving parts, a "brain" consisting of seven radio tubes, and a design that utilized the weapon's own gas pressure to move its fins and create electricity, it was an ingeniously simple but effective weapon.

Due to the success of the Caltech/China Lake rocket program initiated in World War II, China Lake continued to advance rocket technology in the early 1950s. One program, Swoose, was initiated to test the feasibility of using glass-reinforced resin to build rocket casings and document the associated change in the rocket's performance. [144]

Cuban Missile Crisis

In 1962, the Soviets positioned medium-range nuclear missiles in Cuba, with an array of radar stations defending the sites. At the time, the United States did not possess any ARMs; however, Shrike, the first dedicated ARM, was under development at China Lake. To quickly fill this gap, China Lake, in concert with industry, sped up development and produced 200 Shrike ARMs in 6 months, half of them on site. [141]

Vietnam Conflict

Another quick-response effort involving Shrike occurred in Vietnam when China Lake was asked to adapt Shrike to be shipboard launched to destroy or deter North Vietnamese coast defense radars. China Lake was also called upon to adapt the Pave Knife laser target designator to the Navy's A-6 aircraft. In just one example of its potency, Pave Knife helped destroy 14 Vietnamese bridges in 3 hours. In a more general support effort, China Lake acted as the West Coast program coordinator for the Vietnam Laboratory Assistance Program (VLAP). This program was initiated in 1966 to provide support for the Fleet and Marines in Vietnam. Examples of support efforts under the VLAP umbrella include map illuminators, an interim lightweight gun pod, hand-emplaced fuel-air explosives (FAEs) for mine clearance, and small beacons for ground troops to use to identify themselves to friendly attack aircraft. [141]

China Lake also performed a number of tasks that ultimately saved aircrew lives. For example, late in the conflict, China Lake was asked to develop a way to counter a new North Vietnamese antiaircraft missile system. To this end, China Lake performed field tests on available equipment and developed new tactics to engage those targets. Life-saving tactics were also provided by the newly operational Electronic Warfare Threat Environment Simulation (EWTES). The EWTES simulates the EW environment to test equipment and develop tactics. Lastly, China Lake developed IR countermeasure flares urgently needed by the Fleet. [141]

Operation Desert Shield / Operation Desert Storm

When Operation Desert Shield and Operation Desert Storm started in 1990-1991, China Lake was once again tasked with critical, time-sensitive support in direct response to Fleet needs. One effort consisted of a series of laboratory and flight tests to evaluate the Navy's existing bomb fuze inventory. Those tests showed that, if the existing fuze was used in concert with newer fuzes, the bomb would

be safe and effective. As a result, large quantities of fuzes were quickly cleared for use. At Point Mugu, the EA-6B Division quickly adapted Block III and IV HARMs for use against a particularly troublesome Iraqi radar. In a similar effort, Point Mugu also updated the threat files on the ALQ-67 radar warning receiver and the ALQ-126 jammer, and China Lake updated the HARM seeker to recognize the unique targets encountered in Iraq. To this end, China Lake personnel developed new HARM threat files and tested them in an anechoic chamber and with VX-5 aircraft. [49] [140]

Bosnian Conflict

During the conflict in Bosnia, which began in 1992, China Lake operated a Rapid Precision Targeting System (RPTS) in Italy to assist NATO air operations. This effort was recognized with letters of recognition from two generals and with a NATO medal. [54]

Operation Desert Fox

In 1998, the Joint Standoff Weapon (JSOW) Integrated Product Team (IPT) at China Lake helped field JSOWs for carrier air groups deployed in support of Operation Desert Fox in Iraq. These JSOWs constituted some of the first low-rate initial production units produced. China Lake also provided Marine Helicopter Squadron HMLA-367 with some of the latest protective body armor, survival vests, and life preservers. [123] [124]

Operation Allied Force

In support of Operation Allied Force in Kosovo in 1999, China Lake provided the Marine Corps with the Advanced Tactical Airborne Reconnaissance System (ATARS), a digital imaging system that provides nearly real-time high-resolution images in all weather and day and night conditions. In addition, a military/civilian team from China Lake's AWL was in theater to support the deployment. The squadron's commanding officer described ATARS as "indispensable" to the war effort. [120-122]

China Lake was also asked to provide in-theater support for several weapon systems used by the Warfighter. For

example, a Tiger Team from China Lake was deployed to Italy to develop tactical solutions for use with HARM to defeat enemy air defense. China Lake responded to more than 100 Fleet requests for HARM and ALQ-99 (the radar jammer used on the EA-6B) data. It is worth noting that no aircraft were lost to enemy air defense while HARMs were in flight. China Lake was also part of the Joint Direct Attack Munition (JDAM) Kosovo Support Team tasked to provide JDAM capability to Marine F/A-18s. NAWCWD personnel were even sent aboard USS *Kitty Hawk* and USS *Carl Vinson* to provide JSOW training and support. [120-122]

Just as it was during the Bosnian conflict, the RPTS team was again recognized for its "exceptional performance and outstanding contributions" during the conflict in Kosovo. This time, the RPTS team provided a controlled reference image base, a database consisting of highly accurate terrain images and files. [54]

Testing at China Lake also proved highly valuable to the Warfighter, as evidenced by the success of the ALE-50 decoy. In response to anticipated threats in the Kosovo region, NAWCWD tested the Air Force's ALE-50 on the Land Ranges. Air Force officials reported that ten surface-to-air missiles (SAMs) locked onto B-1 bombers but were diverted to the decoy. [122]

War on Terror

NAWCWD supports the War on Terror in many ways, such as hosting explosives classes for the Federal Bureau of Investigation (FBI); however, the following section is concerned only with direct support for Operation Iraqi Freedom and Operation Enduring Freedom. These two conflicts represent the main thrust of a global effort to curtail and ultimately defeat terrorist cells throughout the world. [54]

After the terrorist attacks of September 11, 2001, China Lake set up the Warfighter Response Center (WRC), with three prime directives: maintaining constant connection between warfighters and engineers, providing a secure state-of-the-art meeting place for that team, and functioning

as a central hub for the Naval Air Weapons Station (NAWS) commanding officer in the event of a mishap or natural disaster. Within 5 weeks, an open-storage secret site was created, thereby providing NAWCWD personnel and the Warfighter around-the-clock support. The WRC is a fully functional Naval Aviation Weapons Distance Support Center and is currently the NAVAIR aviation help desk for the Naval Aviation Enterprise. The WRC fields more than 500 support requests annually. [54] [172]

The JDAM quickly became the Warfighter's weapon of choice during the War on Terror, so much so that supply could not always keep up with demand. To fill this gap, China Lake, in only 3 weeks, provided the necessary maintenance to 630 JDAM tail kits needed by deployed Marine Corps forces. In another effort to get JDAMs to the Fleet, Point Mugu was tasked to provide JDAM capability to legacy F-14Bs, and a crew from the F-14A/B/D IPT was sent aboard USS *Theodore Roosevelt*, USS *Abraham Lincoln*, and USS *Constellation* to provide the same capability to the F-14D. [76]

The LCDB and the MAC warhead were two China Lake quick-response efforts to provide the Warfighter with increased capability in urban environments. In both cases, the Fleet needed weapons they could employ in urban environments without unnecessary collateral damage. The LCDB, a laser-guided bomb (LGB) developed by China Lake in under 16 months, can engage enemies in semi-hardened structures, with minimal damage to surrounding structures or noncombatants. For their work on the LCDB, China Lake personnel were awarded the Top Navy Scientist and Engineers of the Year Award in 2007. With development and testing taking approximately 13 months, the MAC warhead was fielded even more quickly than the LCDB. VX-9 played a crucial role in that effort by finishing testing in 4 weeks, an effort that normally takes 4 months. The MAC warhead "can take out the first floor of a building without damaging the floors above," thereby making it a valuable asset in the War on Terror. [54]

NAWCWD also provided critical support to the Warfighter's targeting ability with systems like Digital Precision Strike

Suite (DPSS), Precision Strike Suite–Special Operations Forces (PSS-SOF), Rapid Attack Information Dissemination and Execution Relay (RAIDER), and the Shared Reconnaissance Pod (SHARP). In the battle of Fallujah, DPSS improved the accuracy and timeliness of targeting capability, while reducing the chances of collateral damage. The WRC at China Lake manages deployment of DPSS and other NAVAIR prototype systems. Like DPSS, PSS-SOF significantly increased targeting capability and quickly became the targeting system of choice for both GPS- and laser-guided weapons deployed for close-air support missions, troops in contact missions, and time-sensitive missions. In 2007, three RAIDER systems were deployed to Iraq and Afghanistan, and NAWCWD civilian engineers supported them in theater. For example, the RAIDER team provided USS *Harry S. Truman* with Link-16 capability based on a RAIDER Ground Mobile Gateway System. SHARP was approved for early deployment and provided real-time high-resolution images to ground forces in northern Iraq. SHARP also allowed the central computer on USS *Abraham Lincoln* to download images from F/A-18s and convert them to weapon targeting coordinates. [172]

The ECR at China Lake supported a Joint Fleet Exercise (JTFEX) with USS *John C. Stennis*. Two tent cities, representative of the current conflict, were constructed at Charlie Airfield to provide realistic areas of opportunity for EW-opposed strike missions. The Joint Electronic Warfare Effects Laboratory also provides important EW-related support; for example, in 2009, it completed 59 critical tests that resulted in direct changes to operations. [76] [172]

VX-30 was often sent in theater to support the War on Terror. For example, a crew from VX-30 was tasked with flying a C-130 to Iraq and preparing it to launch five drone aircraft at Baghdad. VX-30 Hornets also flew in support of USS *Abraham Lincoln*, USS *Carl Vinson*, USS *Nimitz*, USS *Ronald Reagan*, and USS *Peleliu*. In 2009, VX-30 deployed four personnel to the Central Command, Atlantic Ocean Range. [69] [172]

VX-31 was also essential to NAWCWD's support of Operation Iraqi Freedom, particularly in support of the Active Electronically Scanned Array (AESA) radar for the F/A-18E/F. In 2009, two individual augmentees from VX-31 were deployed overseas. Their support of Operation Iraqi Freedom earned them a Meritorious Unit Commendation. [172] [177]

Another award, the Edward Heinemann Award for design and modification, was presented to the Intrepid Tiger Pod Team for quickly getting an urgently needed communication system to the Warfighter. NAWCWD and the Naval Air Warfare Center Aircraft Division (NAWCAD) helped the Naval Research Laboratory develop the pod by using recycled mobile Sea Range pods. VX-9 at China Lake performed operational testing on the pod before it was deployed. In 2008, the team released the O-Level Intrepid Tiger Pod. [172] [202]

Ranges

Ranges

Overview

NAWCWD's Land and Sea Ranges are unique DoD national assets. With mountains, deserts, canyons, forests, vast ocean, deep water ports, and islands, all close to one another and within restricted airspace, these ranges are used extensively for T&E and training. More than 1,500 test events occur each year. The ranges 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 Operations Forces units have roamed the desert hills of Superior Valley, and Marine light armored vehicles have raced across the dry flats of Airport Lake during live fire exercises. The ranges have played principal roles in the nation's largest joint service battle experiments. Each year, allied customers, including Australia, Canada, Great Britain, Germany, Switzerland, Italy, and Norway, send hundreds of troops to test weapons and train for conflict. Japan is one of the Sea Range's largest customers.

Ranges are interconnected via a unique Federal Aviation Administration (FAA)-approved restricted corridor (IR-200). Long-range Tomahawk cruise missiles with inert warheads can be launched from the Sea Range to targets on the Land Ranges, so all operational aspects can be tested. In addition, the ranges enjoy great flying weather. Point Mugu has visual meteorological conditions (VMC) 85% of the time and China Lake has VMC 99.5% of the time—in other words, more than 350+ clear days per year.

Land Ranges

The Land Ranges at China Lake represent the Navy's largest single land holding, with 52% of all Navy land worldwide and 85% of the Navy's RDT&E land. The area encompasses 1.1 million acres of land, or 1,700 square miles, and is larger than the state of Rhode Island. The R-2508 restricted airspace encompasses 12% of California's total airspace and is jointly managed by the Navy (China Lake), the Air Force (Edwards AFB), and the Army (Fort Irwin). The ranges support T&E for air and ground conventional weapons, aircraft systems, air-to-air and air-to-surface missiles, rockets, bombs, cluster munitions, cruise missiles, unmanned air vehicles, guns and artillery, fuzes and sensors, mass detonation, training and tactics development, and parachute systems.

Sea Range

The Sea Range at Point Mugu is the largest and most heavily instrumented sea and air range in the United States and encompasses 36,000 square miles of ocean (expandable to 196,000 square miles, from Big Sur south to the United States/Mexico border). The Range Operations Center is capable of monitoring complex full battle group fleet exercises involving aircraft, surface ships, and submarines. San Nicolas Island, 60 miles offshore, is used for littoral warfare training, including theater warfare exercises. San Nicholas Island includes launching facilities and a 10,000-foot-long runway. Point Mugu's 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 EW capability is a core area of expertise and supports the electronic attack EA-6B and the new EA-18G stand-off jammer aircraft for the Navy and the Air Force. The latter aircraft is the only dedicated tactical EW platform in the U.S. inventory.

Environmental Stewardship

As the reader may recall, the Land Ranges encompass more than 1.1 million acres (larger than the state of Rhode Island) and represent more than a half of the Navy's land worldwide. The vast majority of this land acts as a safety and security buffer and remains in a mostly pristine natural state. To keep it that way, a NAWCWD team of archeologists, ecologists, environmental engineers, and specialists under contract perform long-range environmental resource planning and oversee day-to-day environmental projects. For example, NAWCWD developed management plans for preserving endangered species

such as the Mojave ground squirrel, the island night lizard, the desert tortoise, and the San Nicolas Island fox. Policies are also in place to protect birds from aircraft, pinnipeds from missile launches, and wild horses and burros from potential risk on runways. In addition, locations for new facilities and specialized test events are carefully selected to minimize impact, and virtually every mission-related activity is scrutinized to ensure that it complies with environmental laws and regulations. For example, a Final Environmental Assessment and a Finding of No Significant Impact was released in 2008 covering all the new state-of-the-art facilities currently under construction at NAWCWD. [203]

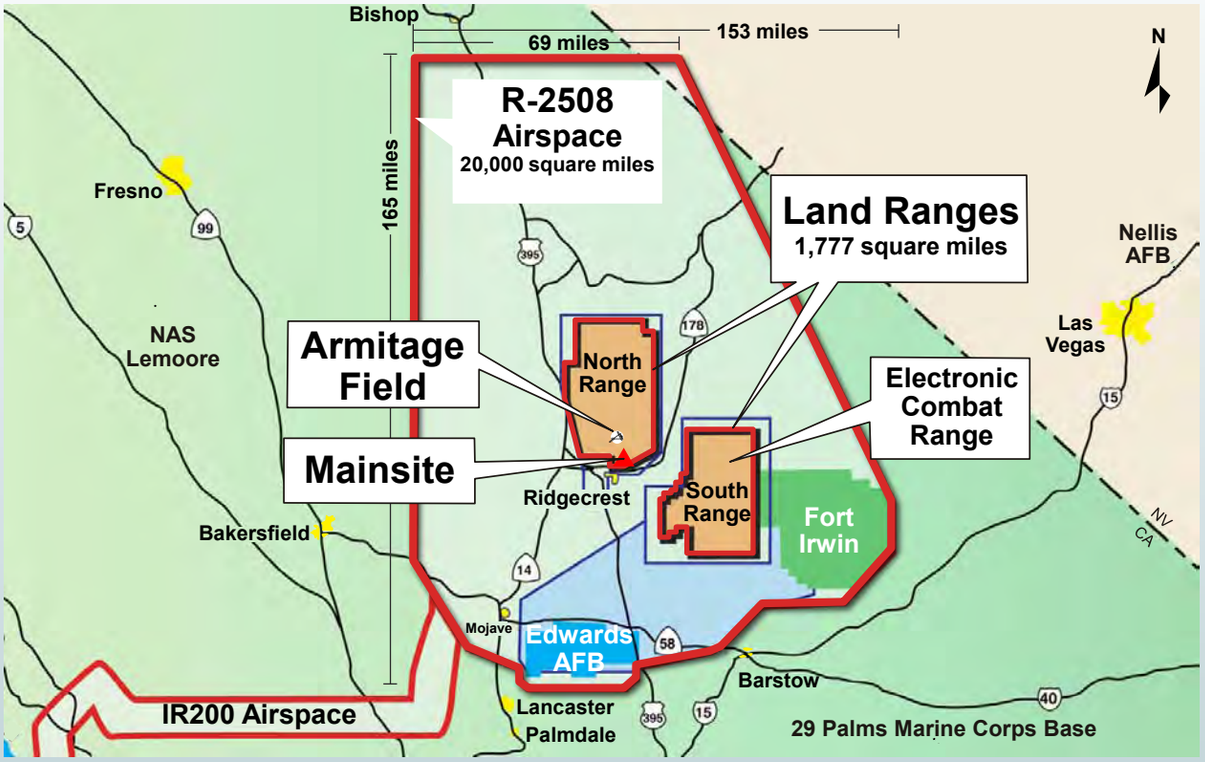
China Lake also protects the valuable desert water sources under its management. To this end, China Lake developed a geographic-information-system-based photographic database for identifying and monitoring its 122 natural water sources.

On San Nicolas Island, isolation has resulted in the evolution of a unique ecosystem. The island is also 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's beaches. To protect that ecosystem, NAWCWD constructed a moveable open-ocean supply pier. This one-of-a-kind pier allows cargo to be transported to and from San Nicolas Island with the least amount of impact on that delicate environment.

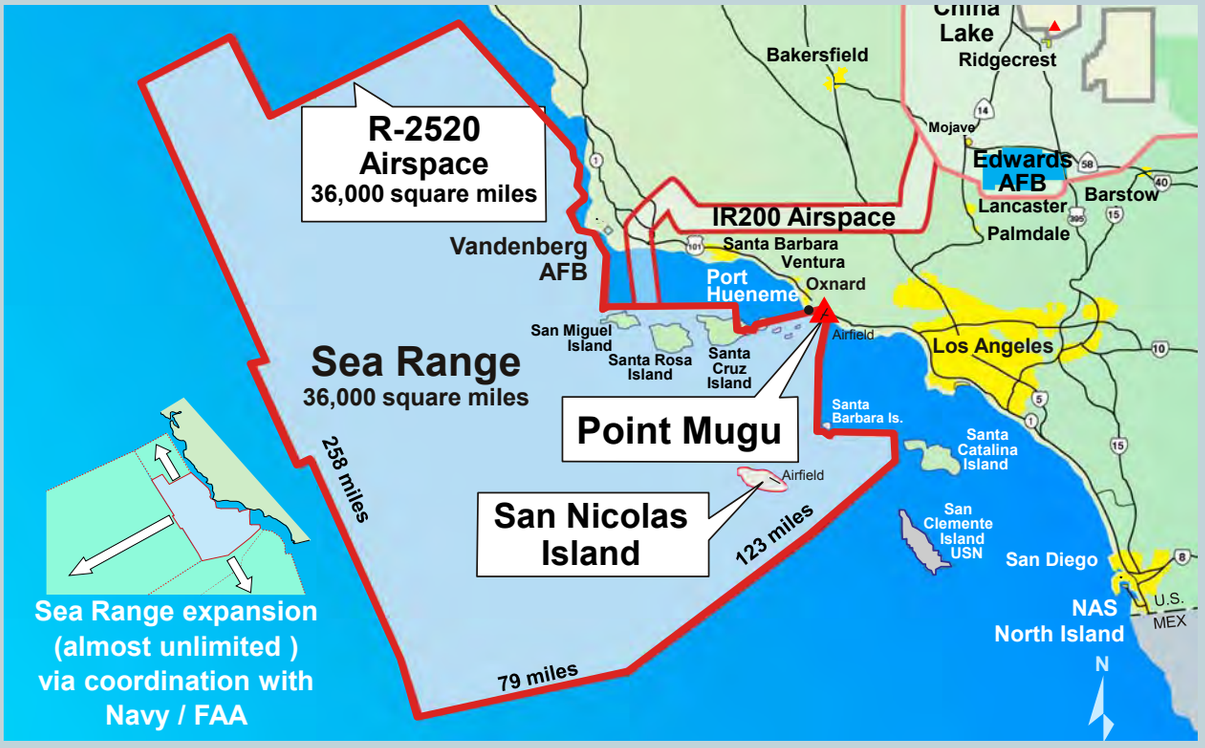
Cultural Stewardship

In another effort to manage and protect its land, NAWCWD conducts cultural resource inventories to identify archaeological, historical, and traditional properties. To date, inventories have been completed on roughly 11,000 acres. One such property is a 100-square-mile collection of ancient rock art. This collection is the largest concentration of rock art in the world and is a National Registered Historic Landmark. In recognition for preserving this unique site, NAWCWD received the Governor's Award for Historic Preservation. No other military installation has ever received this award. [44]

China Lake Land Ranges



Point Mugu Sea Range



“We get great support from the team here on the Land Ranges at China Lake. 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.”

—Raytheon senior engineer

Laboratories and Facilities

Laboratories and Facilities

NAWCWD has more than 40 major facilities, including three airfields, with a replacement value of approximately $2 billion. More than 2,000 buildings encompass 6 million square feet. The state-of-the-art laboratories and facilities at NAWCWD have been key elements to its success through the years. Ranging from the historic 1948 Michelson Laboratory to the 2010 Dr. William B. McLean Laboratory, NAWCWD contains the premier research and development laboratories and facilities required to conduct the work vital to the Navy and the Warfighter.

NAWCWD contains dozens of laboratories on its premises, many of which were built for a specific mission for the Warfighter but perform numerous functions to support basic and applied research and developmental work. The information for laboratories referenced in this section, therefore, represents overviews and does not necessarily highlight all functions performed for the Warfighter.

NAWCWD also contains dozens of facilities on its premises, providing additional RDT&E capabilities to the Fleet. The information for the facilities referenced in this section represents overviews and does not cover all functions performed.

Advanced Weapons Laboratory (AWL)

The F/A-18 AWL provides mission system engineering support for all variants of the F/A-18, coordinating all system upgrades and providing system engineering for F/A-18 hardware and software. In addition, the F/A-18 AWL develops its own integration and simulation laboratories, test equipment, and flight instrumentation. [203] [219]

Chemistry Laboratories

NAWCWD maintains a state-of-the-art research facility staffed with highly trained scientists who clearly understand military-specific technology and Navy needs. Laboratory personnel routinely conduct efforts requiring a rapid response. One example of the facility's many unique capabilities is the High Target Utilization System, which can deposit uniform optical coatings at high rates over much larger areas than standard systems. Facilities include a large well-equipped clean room, which can be utilized for micro/nanofabrication. In the synthetic chemistry laboratories, the synthesis, formulation, and characterization of energetic materials are performed. A few notable examples of important developments stemming from work within these laboratories include hexanitrohexaazaisowurtzitane (CL-20), the most powerful explosive known to date and a formulation that represents a giant leap in the field of energetic materials; space-survivable materials, which have been tested with great success on the International Space Station; and biofuels that are derived from butanol and pinenes that show great promise as renewable high-performing fuels.

Dr. William B. McLean Laboratory

Dedicated to the founder of the Sidewinder missile, the Dr. William B. McLean Laboratory at China Lake is a 177,000-square-foot laboratory that provides more than 50,000 square feet for general engineering, modeling and simulation (M&S), and logistics. Furthermore, this complex, which can accommodate more than 500 people, houses facilities for conferences and symposia. [219]

Electronic Combat Range (ECR)

The ECR is the Navy's principal open-air range for the T&E of airborne electronic combat systems. Facilities provide a realistic electronic combat environment, including threat systems and operation and range control capabilities, as well as instrumentation to obtain time, space, position information (TSPI) and telemetry, optical, and communication data. Other resources include data processing and display, signal monitoring, and calibration systems, as well as assessment and repair facilities for use by T&E and training customers. This complex is the only U.S. DoD ECR having the necessary infrastructure for testing against naval air defense systems and combinations of land and naval systems (littoral threats), either individually or as part of an integrated air defense system. Furthermore, the ECR is the only U.S. open-air EW range that affords realistic simulations of Russian naval systems and their associated shipboard command and control capabilities. As a direct result, TOPGUN student pilots routinely train there against realistic threat radar and SAM systems.

Fire Sciences Laboratory (FSL)

The FSL conducts small- and large-scale fire testing in support of shipboard aviation fire protection, weapons protection, and Navy and Marine Corps shore-based fire protection. The laboratory consists of two primary facilities, the FSL Burn Room and the Carrier Deck Firefighting Test Facility (Mini Deck). The FSL is the only Navy test facility that provides both small-scale testing in controlled weather conditions and full-scale fire testing on site with jet fuel and full flight deck conflagration environmental conditions. These include mass fuel spill, complete hose station capability, wind generation, full-scale weapons and aircraft simulation, and a P-25 firefighting vehicle.

Fuze Test Facility

The Fuze Test Facility at the China Lake Propulsion Laboratories (CLPL) is a new 15,000-square-foot renovation of two existing explosive docks. The facility, operational in fiscal year 2011, provides laboratory space for performing fuze ordnance assessments.

Hardware-in-the-Loop (HWIL) Facility

The HWIL Facility at China Lake is a new 17,000-square-foot state-of-the-art facility that contains two large radio frequency (RF)-shielded anechoic chambers. This facility also provides supporting laboratories for the ESSM and Advanced Medium-Range Air-to-Air Missile (AMRAAM) Programs.

In-Service Engineering Laboratory

The In-Service Engineering Laboratory at China Lake is a new 20,000-square-foot laboratory that provides support for in-service engineering sustainment and maintenance with functions from other activities. [219]

Insensitive Munitions (IM) Facilities

The IM facilities at China Lake provide a secure and safe environment for destructive tests of weapon systems. These tests evaluate munitions reactions from ambient to hot temperatures, extreme immediate hot temperature, rough handling, and hostile environment impacts. Facilities are secure and free from encroachment and frequently provide data for Army and Air Force testing to evaluate and provide safety margin data prior to full-scale manufacturing approval. In explosives tests conducted at the facility's research and development areas, more than 100 tons of ammunition has been detonated to simulate ammunition ship or magazine accidents.

Integrated Battlespace Arena (IBAR)

The IBAR is an advanced simulation facility. Nine interconnected laboratories and facilities provide simulation and analysis—from the subcomponent to theater levels—with a degree of fidelity, flexibility, and dependability unparalleled in the DoD. Facilities are linked worldwide with multiple fiber-optic networks, including the Secure Internet Protocol Router Network (SIPRNET) and Defense Research and Engineering Network (DREN). In addition, the complex offers extensive range microwave telecommunication capabilities. The Virtual Prototyping Facility has the Navy's first cockpit simulation that includes communications to and from the simulated aircraft to the weapons! If live assets are not available, the IBAR can simulate any aircraft, weapon, target, or terrain. Information is networked or data linked through communication systems from any ground, air, or sea platform. The Precision Engagement Center

provides effective targeting and engagement capabilities so that the U.S. military and allied forces can model and rehearse tactical operations and fire integration. In the ongoing War on Terror, IBAR contributes significantly in countering radio-controlled improvised explosive devices (IEDs), EW systems, and unmanned systems (UxS). IBAR engineers and analysts developed a geo-referenced database to register and correlate tactical imagery terrain models based on a database maintained by the U.S. National Imaging and Mapping Agency. The database is used in theater to control raw tactical imagery from which users quickly calculate the precise location of items of interest. The database was used with great success in Kosovo and Iraq and is now being used in Afghanistan operations.

Interoperability Test and Experimentation Complex (ITEC)

The ITEC at Point Mugu links command, control, communications, computers, and intelligence systems during live fire and simulated test events in a controlled, closely monitored range environment. By linking test, training, experimentation, and evaluation assets with live- and synthetic-exercise resources, the ITEC provides a meeting place for the laboratory and warfighters, thereby enabling a flexible mix of laboratory control and operation dynamics. The ITEC is one of only a few facilities within the DoD that offers a land-based Link-16 capability in a littoral setting.

Joint Counter-IED Facility (JCIF)

The JCIF is a specialized facility dedicated entirely to the RDT&E of anti-IED tactics and technologies. It is employed exclusively to produce and deliver "actionable" information pertaining to the performance and compatibility characteristics of counter remote-controlled-IED electronic warfare systems. Terrorism has created its own specialized arsenal of handmade, or improvised, bombs. These devices, often crude in nature, are very inexpensive to build and very deadly to our warfighters. During Operation Iraqi Freedom, these bombs have been the primary cause of United States casualties. In 2005, the Secretary of Defense directed the establishment of the Joint Improvised Explosive Device Defeat Organization (JIEDDO), which then directed China Lake to begin developing the JCIF. The Counter Improvised Explosive Device (CIED) Technical Project Office (TPO) provides daily updates and engineering analysis to fielded forces globally. Information turnaround is as short as 12 hours. The majority of testing is in direct support of requests for information that are generated in theater and prioritized by Combatant Commanders.

Junction Ranch

Junction Ranch provides radar cross section (RCS), microwave measurement, and supporting functions to the Warfighter. This facility maintains a small efficient workforce who works closely with customers; active testing participation is invited and encouraged. Multiple test capabilities are available in one location. Data turnaround is quick, and the facility is capable of supporting competing contractors. Junction Ranch is unique because of its location and radar capability. Due to its remote secure location, there is a minimum level of spurious electromagnetic interference, thus ensuring the highest data quality possible. Surrounded by mountains, the 65-square-mile range and facilities provide precision outdoor RCS measurements of models and real targets, including air, ground, and sea vehicles; very low observables (VLOs); ship models and components; missiles; tactical ballistic missiles; reentry vehicles; ground vehicles; and plumes. The facility is also used to measure antenna patterns and to develop state-of-the-art capabilities in radar, software, and VLO target support functions. This facility can accommodate all levels of security classifications, and environmental clearances are in place to meet customer needs.

Kenneth I. Lichti Range Operations Center

The Kenneth I. Lichti Range Operations Center, located at Point Mugu, is a joint range operations complex built in 2004. This 11.5-million-dollar project includes a 30,000-square-foot multistory structure to house Sea Range test planning, scheduling, and critical data collection functions and equipment, as well as operational synthesis instrumentation and software for interconnectivity of weapons development, test, and evaluation. Also located therein are flight termination systems that can take control of the test articles and then destroy them if they go outside a predetermined envelope. The new warfare concept capabilities of the range center link laboratories and test ranges worldwide to evaluate and improve missiles and weapons for real and simulated battlefield threats. Adjacent to the 36,000-square-mile Point Mugu Sea Range, this addition offers military branches of the DoD and allied forces a multitude of large-scale training involving air-to-air, air-to-surface, surface-to-surface, and surface-to-air exercises. [203]

Laguna Peak Complex

The Laguna Peak Complex at Point Mugu is located on a 1,500-foot-high mountain and provides an elevated line-of-sight location for overlapping coverage of the Sea Range. The facility provides optics coverage, telemetry, airborne and surface target

control, radio communication and data transmission, surveillance radar, and a command transmitter system (CTS) for command destruct. Laguna Peak is also a primary site for range safety CTS for all ballistic missile launches from Vandenberg AFB.

Lauritsen Laboratory

The Lauritsen Laboratory at China Lake is primarily devoted to engineering and research activities, including constructing a direct current plasma jet reactor for diamond deposition. This device produces diamond film, which researchers are developing to grow on metals to create diamond-coated ball bearings and other long-wearing, low-friction applications. [203]

Michelson Laboratory

Michelson Laboratory, which was built in the late 1940s, is one of the primary research complexes at China Lake. This premier facility provides 9.5 acres of floor space and houses an astounding array of talented technicians, engineers, scientists, and program managers with specialized knowledge, talents, and expertise. The laboratory is equipped to support basic and applied research in physics, chemistry, aerophysics, metallurgy, and ballistics, as well as development work in propulsion, fire-control, and guidance systems for rockets. This one-of-a-kind resource provides the infrastructure and intellectual capital to advance the state of the art in RDT&E. During its 60-year history, countless weapons were developed within its walls, including Sidewinder, Spike, and Tactical Tomahawk. [203]

Missile Engagement Simulation Arena (MESA)

The MESA measures the electromagnetic interaction of a sensory system (fuze or guidance) with its intended target. It provides cost-effective, timely, and accurate dynamic missile engagement test data. Missile fuzes are tested against various targets, including full-scale fighter aircraft, in a secure, controlled laboratory environment with all-weather, around-the-clock operational capabilities. It is the only facility of its kind that provides a cost-effective and accurate method of developing, testing, and assessing the performance of proximity fuze systems; validating fuze models and endgame simulations; studying the survivability of platforms; and making live fire test and evaluation (LFT&E) predictions. The ability to model encounters with threat targets under realistic and varied conditions and under laboratory conditions sets this facility apart from outdoor backscatter ranges.

Optics and Laser Research Facility

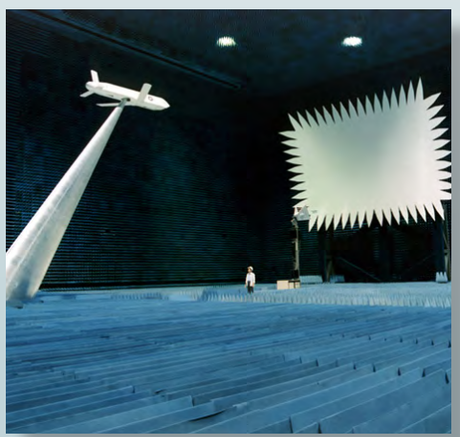
The Optics and Laser Research Facility is located in Lauritsen Laboratory at China Lake. Within this valuable resource, personnel conduct RDT&E on optical materials, components, subsystems, and laser systems. The facility provides cost and time savings to projects because of the rapid prototype

fabrication capability. One example is the production of the 16-inch IR range telescopes that were fabricated at less than half the cost of the commercial estimates, with the first prototypes delivered within only 3 months. [203]

Ordnance and Propulsion Laboratories

The Ordnance and Propulsion Laboratories at China Lake represent the Navy's most comprehensive and truly unique center for research and development of missile propulsion, ordnance, and fuzing. This complex provides a one-stop shop for propulsion and ordnance efforts, including the synthesis of ingredients for propellant and explosives for incorporation into weapon systems, as well as the design of warheads, bombs, fuzes, and rocket motors. [203]

Radar Reflectivity Laboratory (RRL)



The RRL, located at Point Mugu, has three indoor anechoic chambers designed for both near- and far-field monostatic and vertical- and horizontal-plane bistatic RCS measurements at frequencies from very high to millimeter waves. These anechoic chambers provide a test facility designed to minimize the reflections from the interior walls, ceiling, and floor to provide equivalent free-space conditions for performing pristine measurements. Pertinent testing includes far-field RCS; monostatic and bistatic RCS measurements of full-size missiles, targets, and components; and scale-model aircraft and ships for survivability analyses, weapons system flight tests, production/quality assurance testing, diagnostic testing, and the development of scattering models. [203]

Radiographic Inspection Facilities (RIFs)

The RIFs conduct baseline inspections to determine conformance, quality, anomalies, and failure analysis in the inspection of very large ordnance items. X-ray testing is conducted and documentation is prepared regarding the internal configuration of existing and prototype ordnance and non-ordnance items. Frequently referred to as "the world's largest X-ray," the high energy computed tomography inspection system, with digital imaging capability, is used to X-ray systems measuring up to 86 inches in diameter and 27 feet in length and weighing up to 130,000 pounds. It is one of only four highly specialized machines in the United States capable of X-raying the largest submarine-launched ballistic missiles (SLBMs) in the Navy's inventory. In addition, the conventional X-ray facility operates the only operational Betatron 23-million-electron-volt magnetic inductance accelerator in the United States. The RIFs support inspections associated with static firings of rocket motors and large bombs and provide a means to conduct diagnostic inspections. This facility is invaluable in providing quality assurance testing for the various large bomb systems deployed to Iraq and Afghanistan. The Tomahawk

and weapons from various missile intercept programs for Navy and Air Force Programs are regularly tested here. The RIFs are also utilized to evaluate the new Massive Ordnance Penetrator bomb.

Skytop Propulsion Complex

Skytop provides the infrastructure to conduct static test firings of solid-propellant rocket engines, gas generators, and ignition systems, both fielded and developmental. Evaluations at Skytop include those for rocket motors being qualified for future use in complete weapon systems. Also performed there are aging and surveillance studies to ensure that deployed motors are maintaining specific design capabilities. The multidisciplinary technical team at Skytop is highly trained. Full-scale all-up-round motor experimentation is conducted on weapon systems with up to 2 million pounds of thrust and as large as 92 inches in diameter. Developmental and production acceptance tests, as well as aging motor studies of the Navy's submarine-launched Fleet ballistic missiles, have been performed at Skytop, thus ensuring that the United States has the most reliable strategic deterrent system in existence. Skytop has been instrumental in the developmental testing of most tactical air- and surface-launched weapons currently in use by the Fleet.

Supersonic Naval Ordnance Research Track (SNORT)

The SNORT is a 4-mile-long dual-rail precision-alignment track for the testing of rockets, guided missiles, model and full-scale aircraft, and components under free-flight conditions at velocities from subsonic through supersonic. The SNORT is the second longest and fastest supersonic sled track in the world. In fact, items being tested on the track can reach speeds up to 6,000 feet per second. Testing is extremely cost-effective because SNORT combines many advantages of laboratory testing with dynamic free-flight testing and allows test article recovery. Tests performed thereon include long-duration runs and controlled deceleration, aircrew safety, terminal ballistics, rain erosion, vehicle and barrier, aeroballistics, damage and destruction, and soft recovery assessments. Complex multiple target penetration tests using live high-explosive-filled warheads are also conducted. Recently, the cleared target areas at the end of and surrounding the track have been used for IED detection testing. The cleared areas offer a secure, controlled environment to test ground- and airborne-detection and disposal methods.

Thompson Laboratory

The Thompson Laboratory at China Lake was named after China Lake's first civilian Technical Director, Dr. L.T.E. Thompson. Thompson Laboratory is primarily devoted to engineering and research activities, such as developing HARM's Block 3A missile guidance software. [203]

Weapons and Armaments Technology Laboratory

The Weapons and Armaments Technology Laboratory is a new facility at China Lake that opened in 2011. This complex is a 75,000-square-foot facility that contains high-bay and small-bay laboratories to support equipment functions. The laboratory provides logistics weapon support capabilities. [219]

Weapons Dynamic RDT&E Center

The Weapons Dynamic RDT&E Center, a new facility at China Lake, provides dynamic testing of all Navy weapon systems, ranging from all-up rounds to components in all life-cycle configurations. This 7,200-square-foot facility provides vibration testing for transportation, shock, shipboard, and aircraft. [219]

Weapons Survivability Laboratory (WSL)

The WSL is the Navy's field activity for weapon system nonnuclear survivability, weapons lethality, and LFT&E assessments. Therein, survivability testing is conducted for all three major services. The WSL is the largest LFT&E facility in the world, encompassing five major test sites capable of supporting full-scale test articles. This complex also includes an underground site to evaluate smaller-scale articles. It is the only facility with three High-Velocity Airflow Systems (HIVASs) generating flight-representative airflow to operating aircraft. The Missile Engagement Threat Simulator is a high-pressure gas gun capable of precisely delivering "live" man-portable air-defense systems (MANPADS) and other projectiles at high velocities. The threat of one person toting an inexpensive IR-guided shoulder-launched missile and successfully destroying a military aircraft is real! For example, during Desert Storm, several F/A-18 and A-10 aircraft incurred major structural damage from SAMs but, fortunately, managed to return safely to base. In addition, during Operation Iraqi Freedom, when Afghan forces attacked al-Qaeda and Taliban holdouts in one of the biggest battles of the War in Afghanistan, seven Apache helicopters were attacked. However, the aircraft had been redesigned based on WSL LFT&E findings; and, although they were hit, all seven managed to fly home.

Weapons Systems Center for Integration (WSCI)

The WSCI, a China Lake facility that opened in 2010, provides a focal point for weapon development and testing, including weapon M&S, mission-level engineering, and integration. The facility contains four secure laboratories within more than 10,000 square feet of laboratory space. [219]

Weapons Systems Support Activities (WSSAs)

The WSSAs at China Lake afford weapon system support. The WSSA facilities offer a fully controllable environment for executing regression tests and problem investigations. The facility is the only DoD facility that possesses a software development capability, as well as weapon system integration, for the F-14 aircraft. The WSSAs provide periodic functional upgrades due to changing threats, roles, and missions, as well as to correct latent defects or to replace obsolete parts.

“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.”

—Office of the Chief of Naval Material, 1970s

“Mugu was on the leading edge of the missile age.”

—Rear Admiral C. C. Andrews (U.S. Navy, Ret.)

Weapons

AIR-TO-AIR MISSILES

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

The AIM-120 AMRAAM is an all-aspect medium-range air-to-air radar-guided missile designed for air superiority. Specifically, the AMRAAM targets threat air superiority fighters. AMRAAM development began in 1975 to follow and improve upon the AIM-7 Sparrow. Enhancements over Sparrow include a higher speed; greater range; increased maneuverability, reliability, and maintainability; an active radar seeker; and better electronic countermeasure resistance. During development, NAWCWD provided developmental testing, operational testing, aircraft integration testing, performance evaluations, reliability assessments, Fleet introductions, and logistics support. The U.S. Navy declared AMRAAM operational in 1993, and China Lake continues to support this weapon today. [204]

NAWCWD's current role includes development and engineering support, T&E, platform integration, and Fleet logistics and training. In that capacity, NAWCWD affords vital assitance to the Navy's Combat Archer Program and the Navy Weapon Systems Users Program, which evaluate the total air-to-air weapon system capability. Specific China Lake milestones include the first AMRAAM fired from an F-22 and EA-18G. In 2008, the newest AMRAAM, AIM-120D, completed its last year in developmental flight testing with 16 captive-carry flights and 4 launches on the NAWCWD Land and Sea Ranges. [12] [172]

AMRAAM's first combat kill came during Operation Southern Watch in 1992. To date, AMRAAM has shot down a total of nine enemy aircraft, six of which were Serbian aircraft in Operation Allied Force. [204]

Phoenix

The AIM-54 Phoenix was an all-weather long-range air-to-air radar-guided missile designed to counter the threat of Soviet bombers attacking naval carriers. The first variant, AIM-54A, became operational in 1974, followed more than a decade later by the upgraded AIM-54C in 1985. The AIM-54C contained a number of improvements, including a programmable digital signal processor, a digital autopilot, a strap-down inertial measurement unit, a solid-state transmitter/receiver for the radar, and a new rocket motor for increased range (approximately 92 miles). Combined, these improvements significantly increased the Phoenix's chance of intercepting a high-flying, fast-diving air-to-surface antiship missile. The Phoenix was

deployed only on the F-14 Tomcat platform, but that aircraft could carry and fire six Phoenix missiles simultaneously. In fact, an F-14 at Point Mugu demonstrated this very capability by firing all six of its missiles at six different targets in 38 seconds. NAWCWD's role in this weapon system was in the area of test, evaluation, and technical and design support. [27] [204]

In the 1980s, the Navy developed the Phoenix into an extended-range air-to-air missile called the Advanced Air-to-Air Missile. Relying heavily on China Lake efforts, the Navy initiated the Advanced Common Intercept Missile Demonstration of the technology and hardware to support the next-generation Phoenix. However, with the end of the Cold War in 1990, the threat of Soviet bombers was significantly diminished, a situation that, in turn, dramatically reduced the need for a missile of this kind. Therefore, in 1992, the program was canceled.

Sidewinder

The AIM-9 Sidewinder is a short-range air-to-air guided missile used to engage all types of jet aircraft and helicopters. The basic Sidewinder airframe shape and design remain essentially unchanged since the first-generation variant, the AIM-9B, entered service with the U.S. Navy in 1956. However, there is a continuing product improvement program constantly devising new and advanced variants. Highlights from this program include a semi-active laser seeker on the AIM-9C; greatly increased reliability on the AIM-9L; a superior countermeasures capability on the AIM-9M; and a new cryogenic cooler system, also on the AIM-9M. Today, Sidewinder is in its fifth generation with the AIM-9X, which has several enhanced capabilities, including extremely high off-boresight acquisition and launch envelopes, an agile thrust-vector-controlled airframe, a staring focal plane array sensor, and increased range. It should be noted that many of the concepts found in the AIM-9X, like thrust vector control and the high off-boresight capability, were first applied decades earlier to another China Lake missile, the XAIM-95 Agile. Agile was intended as a replacement for Sidewinder, but the technology proved too costly, and the project was abandoned in favor of further Sidewinder enhancements. [46] [144] [204]

In addition to the linear developmental path of Sidewinder as an air-intercept missile, there are also a few divergent paths that led to new uses for Sidewinder. Some examples include the high-altitude performance variant, a Sidewinder with a Sparrow propulsion unit that could engage high-altitude, high-speed targets; SideARM, an air-to-surface ARM based on AIM-9C; the Rolling Airframe Missile (RAM), a ship-launched point defense missile based on Sidewinder's rocket motor, fuze, and warhead; and Chaparral, the Army's surface-launched variant.

China Lake conceived, designed, and developed the Sidewinder in the early 1950s under the direction of Dr. William B. McLean and continues to employ a similar full-spectrum capability today. For example, NAWCWD is exploring a new warhead and a new rocket motor for a possible AIM-9X

Block III missile that is under consideration, helping to develop a new active optical target detector, continuing flight tests on the AIM-9X Block II, and refurbishing AIM-9M all-up rounds for FMS. Sidewinder remains a major foundation for technological developments at China Lake, and, as such, the two remain inextricably interconnected. [172]

Sidewinder was first deployed in combat when Nationalist Chinese forces engaged the Communist Chinese Air Force over the straits of Formosa in 1958. Its first large-scale use came during the conflict in Vietnam, where Sidewinder was credited with the majority of air-to-air kills. Today, all U.S. and allied fighter aircraft operating in support of Operation Enduring Freedom carry Sidewinder. [141] [204]

Sparrow

The AIM-7 Sparrow is an all-aspect medium-range air-to-air radar-guided missile. The Sparrow began in the 1940s in a Sperry Gyroscope Company program known as Project Hotshot. The objective was to develop a radar-beam-riding missile, which was designated AAM-N-2. The missile achieved its first direct hit in 1952—the first U.S. kill of an airborne target by an air-launched vehicle. The missile achieved another significant first in 1955, when it was successfully launched against a high-speed target. Sparrow I entered service in 1956 but was never a success because it was restricted to visual-range engagements only because of the beam-riding guidance system that was slaved to an optical sight in the cockpit. To correct this discrepancy, attempts were made to develop an active radar-guided Sparrow (Sparrow II), but this technology was ahead of its time, and the program was canceled in favor of a semi-active radar-guided Sparrow (Sparrow III). This version of Sparrow (now designated the AIM-7C) entered the Fleet in 1958 and formed the basis for all future generations of Sparrow. [50] [136] [204]

Point Mugu was involved in evaluating every variant of Sparrow since its inception. Those efforts included the first successful test, in which Sparrow I rode a radar beam; the first air launch of Sparrow I, II, and III; and the first kill for all three variants. China Lake began working on Sparrow in the early 1970s, after its disappointing performance during the conflict in Vietnam. China Lake resolved the performance and reliability problems encountered and assisted in the development of a second source for production as tasked but also initiated design corrections and improved the documentation package for the system. The result was "a greatly reworked high-performance, highly reliable, lower-cost Sparrow missile system." Today, most of NAWCWD's efforts with Sparrow focus on the SeaSparrow and the ESSM. [50] [141]

The first combat kill by a Sparrow came in 1965 when the U.S. Navy shot down two North Vietnamese MiG-17s. In all, more than 50 aircraft were shot down by Sparrow during the Vietnam conflict. Sparrow was last used in combat during Operation Desert Storm, in which approximately 25 Iraqi aircraft were successfully engaged and defeated.

Air-to-Surface Munitions

The "Eye" Series

In its capacity as the Navy's lead laboratory for free-fall weapons, China Lake developed the "Eye" series of weapons in the early 1960s to improve the Navy's air-attack capability. Weapons in the "Eye" series include Briteye, Deneye, Fireye, Gladeye, Padeye, Sadeye, and Snakeye; however, Walleye and Rockeye (specifically the Mk 20 Rockeye II cluster bomb unit [CBU]) stand out as having had the greatest impact on the Fleet.

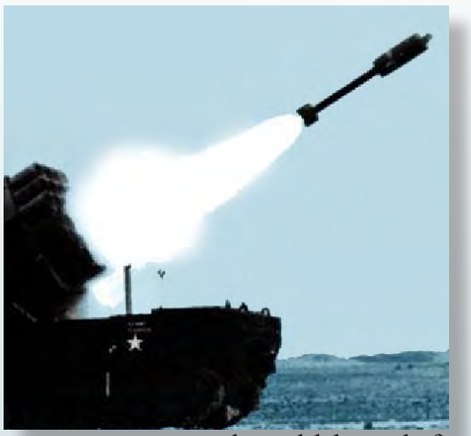
The AGM-62 Walleye, a precision-guided air-to-surface glide bomb based around the Mk 83 general purpose bomb, was intended primarily for use against soft, stationary targets. The Walleye II, based around the 2,000-pound Mk 84, was designed to increase Walleye's effectiveness against hard targets. Each Walleye also came with an extended-range variant to increase standoff capability. Conceived, designed, developed, and tested by China Lake in the early 1960s (the weapon was fielded in 1967), Walleye was the first precision-guided air-to-surface weapon. A small television camera mounted in the nose of the bomb transmitted images to the cockpit, where the pilot could designate an aimpoint and release the bomb. After release, it would direct itself to the target, thereby allowing the pilot to turn away from the aimpoint in true fire-and-forget fashion. Although no longer in service, the Walleye proved to be a milestone in guided weapon systems. [204]

The Mk 20 Rockeye II CBU is an unguided free-fall cluster weapon intended for use against tanks and armored vehicles. A follow-on after the canceled Mk 12 Rockeye I Program, the Rockeye II was fielded 1 year after Walleye. While there are several different tactical munitions dispensers, the Rockeye II is the most widely used and has been in high-rate production for many years. Rockeye serves as the backbone for the CBU-59 Antipersonnel/Anti-Materiel (APAM) and CBU-78/B Gator bombs, which are still in service today. During Operation Desert Storm, the U.S. Navy, Marines, and Air Force dropped a staggering 27,987 Rockeyes. [204]

Fuel-Air Explosive (FAE) Weapons

FAE weapons use an explosive charge to create an aerosol cloud of fuel in the air, which is then ignited by a detonator, thereby creating high overpressure useful against soft targets in protected areas, such as personnel in trenches, as well as clearing mine fields and landing zones. China Lake had full-spectrum capability on several FAE weapons, including the CBU-55A/B, CBU-72/B, BLU-95, BLU-96, APAM, and several others.

The first FAE weapon was the CBU-55/B. It was a 500-pound CBU loaded with three BLU-73/B bomblets containing ethylene oxide liquid fuel that creates an aerosol cloud roughly 45 feet in diameter and 8 feet thick. It entered service with the U.S. Marine Corps in 1969 and saw



immediate action in Vietnam clearing mine fields. In 1971, after extensive operational testing in Vietnam, this weapon was adopted by the U.S. Navy and was last used during the Gulf War in Iraq to clear mine fields. The CBU-55/B could be deployed only by low-speed or rotary-wing aircraft, so China Lake developed a low-drag version that could be deployed from high-speed fixed-winged aircraft. The new variant, redesignated CBU-72/B, went into service for the U.S. Navy at the same time as the CBU-55/B and was also last used in active service in the Gulf War. China Lake also produced the BLU-95/B (500-pound) and BLU-96/B (1,000-pound) FAE II weapons. Both bombs served the same purpose and could launch from the same platforms as the CBU-55/B and CBU-72/B but contained propylene fuel. A surface-launched FAE was also developed by China Lake to clear safe paths through mined areas, a feat particularly suited for FAEs because they could be used in proximity to friendly forces due to their lack of long-range fragments. [204]

Gator

Gator is an antipersonnel, antitank air-to-surface unguided munitions delivery system used by the U.S. Navy, Marine Corps, and Air Force against area targets such as tanks, armored vehicles, trucks, radar installations, SAM sites, parked aircraft, and other materiel. Gator mines have a programmable self-destruct feature that permits the battlefield commander to control the timing of a counterattack or defensive maneuver. The Navy's CBU-78/B Gator is a 500-pound cluster weapon that uses the Mk 7 Rockeye dispenser, while the Air Force's CBU-89 Gator is a 1,000-pound cluster munition.

Gator is the successor of Deneye, an antitank mine delivery system developed by China Lake in the early 1960s as part of the "Eye" series of free-fall weapons. Though Deneye never reached production, Gator began production in 1982 and is still in service today. To make Gator a reality, China Lake helped adapt Army-developed land mines to Navy and Air Force dispensers. NAWCWD is currently responsible for in-service engineering and logistics support.

During Operation Desert Storm, China Lake increased Gator weapon delivery by a factor of four. Gator performed so well that United States forces employed more than 1,000 Gators to limit the mobility of the Iraqi Army and hamper Iraqi movement in areas known to hide Scud missile launchers.

General Purpose Bombs

The Mk 80 weapon series, which include the 250-pound (Mk 81), 500-pound (Mk 82), 1,000-pound (Mk 83), and 2,000-pound (Mk 84) bombs, are free-fall air-to-surface unguided general purpose bombs. The Mk 80 series were developed in the 1950s in response to the need

for bombs possessing less aerodynamic drag for operation on jet aircraft. The bombs are fitted with one of several nose or tail fuzes to meet specific tactical needs, such as fragmentation, blast, cratering, or penetration. The Mk 80 series have undergone several modifications, generally minor in nature and mainly concerned with the explosive filling, fuzing, and delivery methods. Two notable changes include several types of retarding tail units developed to aid delivery during high-speed, low-level attacks, as well as the addition of PBXN-109 insensitive high-explosive fill. Mk 80 series bombs with this fill were redesignated BLU-111, BLU-110, and BLU-117, respectively. General purpose bombs are used against an extensive array of targets, including artillery, trucks, bunkers, Scuds, and SAM sites. China Lake and Point Mugu have been actively involved with RDT&E of bombs since World War II. Consequently, China Lake became the Navy's lead laboratory for free-fall weapons in the early 1960s. Today, NAWCWD's involvement continues apace with the Insensitive Munitions (IM) Bomb Project, the LCDB, and the Cast Ductile Iron Practice Bomb. [172] [204]

The IM Bomb Project is a joint U.S. Air Force/U.S. Navy effort to develop a common design and explosive for general purpose bombs that will meet new and demanding IM requirements. The first phase focused on improving fast and slow cookoff responses. To this end, NAWCWD engineers designed, developed, analyzed, and incorporated an aft vent plate design into all three weight variants. The team adopted a collaborative systems approach, thus enabling them to devise a low-risk, cost-effective solution affording the highest value to the Navy and Air Force. In addition to the aft vent plate, NAWCWD scientists supported the Air Force with analysis and qualification of a new explosive for the 2,000-pound bomb and devised a forward fuzewell release system for the 500-pound bomb that may be used in the 1,000-pound bomb as well. Testing indicated that the fast and slow cookoff reactions satisfied the pertinent criteria. The next phase of IM improvements, designed to mitigate the reaction of the bombs to external shock stimuli, began in 2010 and will continue through 2013. [172]

Designated the BLU-126/B, the LCDB was developed by NAWCWD in 2007 in response to a Fleet need for close-air support in urban environments, where the reduction of collateral damage is paramount. The BLU-126/B is externally identical to the 500-pound BLU-111 but contains less explosive mass, thereby resulting in a 90% decrease in the number of fragments generated and a greater than 50% reduction in the range in which collateral damage occurs. Because the LCDB is a modification to an existing weapon and, as a result, does not require unique support, it is a highly cost-effective weapon. At the end of 2008, IM Bomb Project design improvements were integrated into the BLU-126/B,

and IM testing was done on the resulting BLU-126A/B. LCDB was transitioned to the Single Manager for Conventional Ammunition on 24 June 2009. [172]

In partnership with the U.S. Air Force, NAWCWD is developing new live and practice 500-, 1,000-, and 2,000-pound bomb bodies. This effort is an attempt to expand the industrial base for the Mk 80 series bomb bodies, provide an alternative to the current single source, and allow for a competitive environment to reduce unit cost. Historically, general purpose bomb bodies were made of forged steel, but there are few producers of this kind of body, and fabrication is time-consuming and costly. New cast ductile iron techniques mitigate these problems, eliminate the need for concrete filler in practice bombs, and allow those same practice bombs to be rebuilt and reused. The 500- and 2,000-pound bomb bodies are in production, and development and testing on the 1,000-pound bomb body began in 2010. [172]

General purpose bombs are used repeatedly by U.S. forces in combat. There is no better example of that fact than the U.S. Air Force report stating that its service alone used approximately 114,000 Mk 80 series bombs over the course of Operation Desert Shield and Operation Desert Storm. The first LCDB drop occurred during Operation Iraqi Freedom in July 2007, and the bomb performed exactly as designed. [172] [204]

Joint Direct Attack Munition (JDAM)

The JDAM is a low-cost strap-on GPS/inertial navigation system (INS) guidance kit that converts free-fall air-to-surface unguided bombs, or "dumb" bombs, into accurately guided "smart" munitions. JDAM was developed to meet the need for an adverse-weather, accurate-strike capability in response to lessons learned during Operation Desert Storm. JDAMs upgrade the existing inventory of 500-pound Mk 82, 1,000-pound Mk 83, and 2,000-pound Mk 84 general purpose unitary bombs and the BLU-109 2,000-pound hard-target penetrator bombs. [172] [204]

The JDAM is a joint U.S. Air Force/U.S. Navy weapon system, with the U.S. Air Force acting as the lead service. NAWCWD serves as the Navy's lead field activity for JDAM, while also providing Fleet technical support, as well as support for contractor testing, mission planning and development, and logistics. NAWCWD played a major role in the integration of JDAM on several platforms, including the F/A-18C/D/E/F; the F-14B/D; the AV-8B; and, in 2009, the MQ-9 Reaper. In the late 1990s, NAWCWD demonstrated the Direct Attack Munition Affordable Seeker (DAMASK) concept, which sought to improve JDAM's 10-meter accuracy to 3-meter circular error probability. Although a contract was awarded in 2003, funding was cut in 2004, and the effort was transferred to the U.S. Navy's Small-Diameter Bomb (SDB) Program. Working closely with the Air Force at Eglin, NAWCWD also helped field the Laser Joint Direct Attack Munition (LJDAM) system in October of 2008. This system was designed to address a gap in engaging moving targets by retrofitting a precision laser guidance

kit to existing GBU-38 series JDAMs. Due to the success of DAMASK and LJDAM, NAWCWD was once again selected to participate in the development, test, and evaluation of another JDAM variant—the JDAM Assault Breaching System (JABS). Designed for use in littoral environments, JABS will incorporate a prototype warhead and the existing JDAM guidance kit to neutralize mines ahead of U.S. forces by firing darts from a submunition dispenser. It is a follow-on effort from a successful demonstration conducted in 2008 in which Mk 84 JDAMs were released into 40- and 25-foot-deep ponds constructed on the China Lake ranges. Prototypes of this weapon are scheduled for demonstration in fiscal year 2014. [22] [172] [204]

The JDAM was first deployed in 1999 during Operation Allied Force in Kosovo, where at least 50% cloud cover existed for more than 70% of the time. It was during this time that JDAM proved its accuracy and all-weather capability, with an 89% hit rate reported by the Air Force. Its track record in Kosovo led to JDAM's extensive use throughout Operation Iraqi Freedom. More than 6,500 JDAMs were dropped during Operation Iraqi Freedom. JDAM use increased further in Operation Enduring Freedom, with more than 7,000 drops by Air Force and Navy against Taliban al-Qaeda targets. [55] [204]

Laser-Guided Bombs (LGBs)

LGBs are air-to-surface precision-guided bombs designed for use against all types of surface targets. As the name implies, LGBs use a nose-mounted laser guidance and control system in concert with tail fins to direct the weapon to the target. U.S. Navy variants include the GBU-10 (2,000-pound Paveway II), GBU-12 (500-pound Paveway II), GBU-16 (1,000-pound Paveway II), and the GBU-24 (2,000-pound Paveway III). [204]

China Lake's work with LGBs began in the late 1960s while helping the Air Force adapt its Pave Knife laser target designator pod to the Navy's A-6 aircraft. In the 1980s, China Lake developed a rocket-propelled version of the GBU-16 that went into production in 1985 as the AGM-123 Skipper. More recently, NAWCWD designed, tested, and built the BLU-116A/B warhead for the hard-target penetrator LGB designated GBU-24G/B and developed the Dual-Mode Laser-Guided

Bomb (DMLGB) in a successful quick-response effort in which 4,000 DMLGBs were delivered. In 2005, NAWCWD began an effort to improve the impact accuracy of the Laser-Guided Training Round. Hardware and software changes were made, testing was performed, and deliveries went to the Fleet in 2006. Today, NAWCWD continues to play a vital full-spectrum role in LGBs, including cradle-to-grave responsibility for the GBU-24E/B. [172]

In an often repeated quote, it was said that "[in] World War II it could take 9,000 bombs to hit a target the size of an aircraft shelter. In Vietnam, 300. Today, we can do it with one laser-guided munition…" For that reason, LGBs played a significant role in the major conflicts of the 20th century and continue to do so in the 21st. For example, 8,400 LGBs were used in the Gulf War, while more than 8,600 were used in Operation Iraqi Freedom. [206]

Air-to-Surface Missiles

Bulldog

The AGM-83 Bulldog was an air-to-surface laser-guided missile designed for use in close-air support by the U.S. Marine Corps. Bulldog's large delivery envelope, long-range and low-altitude fire capability, and low cost made it ideal for destroying small ships, bridges, tanks, and similar stationary and mobile targets. [205]

The AGM-83 was conceived, designed, and developed by China Lake as a replacement weapon for the AGM-12 Bullpup, which was used considerably in Vietnam but had several operational problems. Designed around the Bullpup airframe, the Bulldog incorporated components from existing weapon systems wherever possible, including a significant amount of Sidewinder technology for the guidance system. The Bulldog solved the problem of using liquid fuel aboard aircraft carriers by the incorporation of the Mk 8 Mod 2 solid-propellant motor, reduced the vulnerability of the launch platform to ground fire during weapon delivery, and improved performance against hard targets. Bulldog was the first successful laser-guided missile; however, in 1974, manufacturing and deployment were cancelled in favor of the Air Force AGM-65 Maverick. [144] [205]

Condor

The AGM-53 Condor was a long-range air-to-surface television-guided supersonic cruise missile designed to provide the U.S. Navy a standoff capability against heavily guarded, high-value, and strategic targets. The basic Condor was followed by two major improvements: first, the television guidance was replaced with a dual-mode seeker consisting of a radar and a small television camera to improve capability in all weather conditions; second, the solid rocket motor was replaced by a turbojet engine to provide extended-range capability. [144] [205]

China Lake was the lead field activity and technical manager responsible for initial development and also provided the technical direction for the dual-mode seeker, turbojet design, systems engineering, guidance, fuzing, warhead development, system safety, propulsion, aircraft interface, and cost analysis. The Condor completed development, testing, pilot production, and long lead production; however, Congress canceled funding for production in 1976 due to cost overruns. [144] [205]

Hellfire

The AGM-114 Hellfire (Heliborne Laser Fire and Forget) is a close-in point defense air-to-surface precision-guided missile designed to engage tanks and armored vehicles, both stationary and moving. The first three generations used a semi-active laser seeker, while the fourth generation, the Longbow Hellfire, uses a millimeter wave seeker.

The Hellfire Program was initiated by the U.S. Army in the early 1970s, with the first guided launch occurring in the late 1970s and Fleet entry coming in the mid-1980s. The Hellfire system is constantly evolving in response to new technologies and Fleet needs. The Marine Corps received a version with a low-smoke motor and safety-and-arming device (SAD) (AGM-114B), and the Army received the same version but without the SAD (AGM-114C). The AGM-114F came with a new warhead to defeat reactive armor. The AGM-114K, the first in the Hellfire II series, solved many of the deficiencies of the original Hellfire, like the backscatter problem, while incorporating new elements to improve its capabilities, such as a more-powerful warhead and a digital autopilot. The other Hellfire II variant, the AGM-114M, is equipped with a blast fragmentation mechanism for use against more-general targets. The next-generation Hellfire, the AGM-114L Longbow Hellfire, replaced the laser seeker with a millimeter wave system to allow Hellfire to be used day or night in all weather conditions. Hellfire then received a new MAC warhead for increased lethality, resulting in the AGM-114N. The AGM-114R, the future of Hellfire, is designed to replace all previous variants and become the sole Hellfire variant in use. [204]

Though the Hellfire was initiated by the Army, China Lake is closely involved with this weapon system. In general, China Lake's Tactical Weapons Office serves as assistant program manager for systems and engineering and as 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 Hellfire. In particular, China Lake developed the MAC warhead used in the AGM-114N. MAC warheads have a sustained pressure wave in comparison to the sharp

spike and rapid decay of conventional warheads. Even though the MAC warhead was not released to the Fleet until the early 2000s, its development began in the 1960s, when China Lake started conducting experiments on FAEs. By the 1980s, China Lake successfully developed nonliquid FAEs that would become the precursor of the MAC warhead. In 2003, China Lake became the technical design agent for the MAC warhead and produced several hundred over the next few years before transferring the program to industry. In addition to the MAC warhead, China Lake continues to support development of the AGM-114R to ensure that it meets Navy requirements, specifically in relation to Military Operations in Urban Terrain targets. [172]

The Hellfire was first deployed in combat in 1989 during Operation Just Cause. During Operation Desert Storm, the U.S. Army used about 4,000 Hellfire missiles. By mid-2007, more than 3,000 Hellfires were used in support of Operation Iraqi Freedom and Operation Enduring Freedom. It was during Operation Iraqi Freedom that the first MAC Hellfire was used in combat. [204]

Joint Air-to-Ground Missile (JAGM)

The JAGM effort is a follow-on program to the Joint Common Missile Program, which was canceled in 2007. Its objective is to provide a replacement missile for Hellfire; Maverick; and the Tube-Launched Optically Tracked Wire-Guided missiles on rotary-wing, fixed-wing, and unmanned platforms. The JAGM is intended to engage a variety of targets, including advanced heavy/light armored vehicles, bunkers, buildings, naval patrol craft, command and control vehicles, transporter/erector launchers, artillery systems, and radar/air defense systems. [204]

NAWCWD plays a significant supporting role for each of the contractors in the JAGM Program. For example, NAWCWD supports M&S, which is a significant aspect of the JAGM Program. In particular, NAWCWD is working with the Army Aviation and Missile Research, Development, and Engineering Center on a maritime module for the Army's common scene generator to complement the existing land-based modeling. NAWCWD contributes to a number of program reviews, including initial baseline reviews, systems requirements reviews/systems functional reviews, test readiness reviews, and preliminary design reviews. NAWCWD also provides personnel for IPTs, working groups, and failure review boards, as well as providing contractor analysis documents, white papers, technical guidance documents, and supporting research. [172]

Joint Standoff Weapon (JSOW)

The AGM-154 JSOW is a standoff-outside-point-defense air-to-surface laser-guided glide weapon used to engage a variety of targets, depending upon the variant employed. JSOW comes in three main variants: the baseline version, which deploys 145 bomblets for area targets; the antiarmor version, which carries six bomblets for armored targets; and the unitary version, which has a dual-stage warhead for blast/fragmentation and penetration of point targets. [204]

China Lake's involvement with JSOW really began in the late 1980s while serving as the lead field activity for the Advanced Interdiction Weapon System. When the Air Force joined the program in 1992, the weapon system was renamed JSOW. China Lake provides support for systems engineering, flight test planning, logistics and training, and developmental and operational testing and conducts Fleet introduction and interface; in fact, the first flight test took place at China Lake in 1994. In 2008, China Lake supported the completion of JSOW Block II operational T&E, which culminated in the weapon's release to the Fleet in August of 2008. NAWCWD supported development of the AGM-154C-1 (JSOW Block III), with a successful critical design review in 2008, tests of a low-cost warhead under consideration in 2009, and a successful captive-carriage flight in 2010. [172]

The first operational use of JSOW came in 1999, when U.S. Navy aircraft launched three AGM-154As at three separate Iraqi surface-to-air sites during a routine patrol of "no-fly" zones. The United States Navy continued to employ JSOW in Iraq in support of Operation Iraqi Freedom. Current figures from Raytheon put the total number of JSOWs used in combat at 400. [204]

Maverick

The AGM-65 Maverick is a standoff-outside-point-defense air-to-surface guided missile used against a variety of targets. Mavericks can have a television, laser, or IR guidance system. There are also two warhead variants, the 125-pound shaped charge and the 300-pound blast penetrating warhead. The Maverick can be fired from both high and low altitudes. The U.S. Navy and Marine Corps use the AGM-65E (300-pound laser-guided) and the AGM-65F (300-pound IR-guided) versions of the Maverick.

While the system was originally developed for the Air Force in the 1960s, China Lake became involved in modifying and refining the system. For example, China Lake helped integrate the weapon on the A-4, A-6, and A-7 platforms. Today, China Lake's Tactical Weapons Office serves as assistant program manager for systems and engineering and class desk for the NAVAIR Defense Suppression Systems Office. In that capacity, China Lake supports the Navy and Marine Corps variants from cradle to grave. Point Mugu serves as assistant program manager for logistics and as the Fleet support team for integrated logistics support. NAWCWD is currently lending

its support to the Enhanced Laser Maverick (AGM-65E2) Program initiated to address the need for a close-air support weapon capable of engaging moving targets. Specifically, the Tactical Weapons Office provides systems engineering support and acts as the lead for developmental testing. Thus far, China Lake has conducted two successful seeker tower tests and developed systems requirement review and preliminary design review plans and is currently conducting the critical design review. [25] [172]

The Maverick has been deployed in every major conflict since its release in 1972. Its first combat use came during Operation Desert Storm, in which approximately 5,300 were deployed. To put into perspective just how heavily that weapon was used in that conflict, it should be noted that, during Operation Allied Force and Operation Iraqi Freedom only, a combined total of approximately 1,700 were used. The Maverick is still active today in Operation Enduring Freedom in support of the War on Terror. [204]

Rockets

In 1943, news of German aircraft rockets reverberated throughout the United States, prompting a crash program to develop forward-firing aircraft rockets. The United States responded with aplomb, and, by 1944, rockets were major weapons of war, with the Army spending $150,000,000 a year on rockets and the Navy spending eight times that amount. China Lake quickly took the lead in full-spectrum rocket work, developing rockets and their sundry parts, as well as training Fleet squadrons at its ranges. China Lake conducted more than 1,000 projects by the end of World War II, prompting *Life* magazine to dub China Lake "Rocket Town" in 1948. This early work laid the foundation for China Lake's future and the future of naval weapons.

Rockets are air- and surface-launched unguided ballistic trajectory weapons propelled by the controlled burning of energetic materials. Early rocket development included several types and sizes, like the 3.5-inch fixed-fin rocket, the first forward-firing aircraft rocket used by U.S. troops in World War II, but a few specific weapon systems stand apart as having special historical significance and as having played a substantial role in shaping current naval weapon systems.

Rockets, 5.0-Inch Variants

The Zuni rocket is a 5.0-inch air-to-surface unguided folding-fin rocket developed in the 1950s. It replaced an earlier version of the 5.0-inch rocket, also developed at China Lake, called Holy Moses, and was initially intended for air-to-air combat but later evolved into an

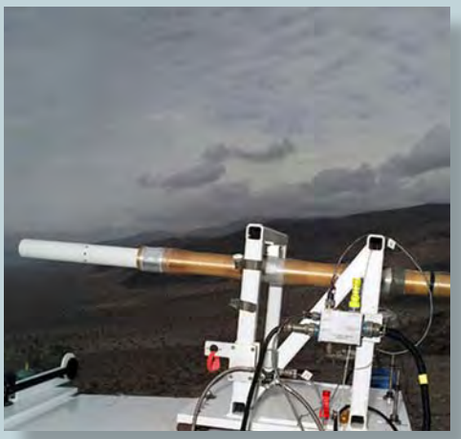
air-to-surface weapon. Released to the Fleet in 1960, the Zuni has been used heavily in combat and is still in service today, with the same basic design. Minor changes of note include an improved rocket motor (Mk 71) and a new wrap-around fin design. [141] [204]

Today, however, the Zuni is undergoing a major change in capability as a result of a Marine Corps requirement for a precision-guided forward-firing weapon to replace the AGM-65 Maverick. In 2005, MBDA Inc. and China Lake entered into a Cooperative Research and Development Agreement (CRADA) to produce a laser-guided Zuni rocket. In May 2009, a laser-guided Zuni launched from the ground successfully hit a stationary target. The following August, another ground-launched laser-guided Zuni successfully struck a moving target. [204]

Rockets, 2.75-Inch Variants

Developed in the 1940s, the 2.75-inch rocket (nicknamed Mighty Mouse) is an air-to-air unguided folding-fin rocket. It was designed to attack high-speed heavy bombers and was employed heavily by all services of the U.S. Armed Forces, with approximately 50 million produced by 1973. Like the 5.0-inch rocket, the 2.75-inch rocket remained relatively unchanged (apart from an upgraded motor [Mk 66] and a wrap-around fin design) until recently. But now, it too is receiving increased capability, in this case, from the Advanced Precision Kill Weapon System (APKWS) and the LOGIR Programs. [172]

The APKWS effort is a Navy-led program to enhance the 2.75-inch rocket with a laser-seeking guidance and control system to meet the need for a laser-guided rocket. The APKWS Program began in the late 1990s as an Army program, but, after setbacks involving performance, schedule, and cost, it was taken over by the Navy in 2008. In 2010, successful operational assessment launches cleared the APKWS to enter low-rate initial production (Milestone C). [172] [204]



The LOGIR Program is funded by an Office of Naval Research's (ONR's) Future Naval Capabilities effort and was initiated in 2000 to significantly improve the Warfighter's ability to engage moving and fixed targets, with an emphasis on moving targets, specifically maritime fast inshore attack craft. LOGIR is a low-cost thermal imaging kit designed to improve the accuracy of 2.75-inch rockets. LOGIR has a range of approximately 7.5 kilometers for improved standoff capability and has a very large launch acceptability region, thereby enabling the aircraft to quickly target and engage combatants. In

concert, these two characteristics allow the aircraft to attack large numbers of targets in a single sortie, while reducing pilot exposure. In 2008, at the China Lake ranges, the LOGIR Program successfully launched its first guided round, which hit the target nearly dead center. The second guided launch took place at San Nicolas Island in late 2009, with the intent to test LOGIR against a threat representative of a fast inshore attack craft. Unfortunately, failures in both the inertial measuring unit and the contract actuation system prevented success. Unfazed, China Lake personnel solved the problems and successfully completed a third guided launch in early 2010, which ended the demonstration program and moved LOGIR into the Medusa Joint Capability Technology Demonstration (JCTD) phase. The Medusa JCTD will integrate LOGIR and a new LOGIR rocket launcher onto the MH-60S platform. [172] [204]

Antitank Aircraft Rocket (ATAR)

The ATAR was another China Lake rocket developed to meet specific warfighter needs. During the Korean War, United States forces needed rockets capable of penetrating heavily armored tanks. In an astounding 29 days, China Lake designed, developed, tested, produced, and delivered 200 provisional rockets to the Fleet, with the final design entering production within 3 months of the initial request. The new rockets could penetrate 17 inches of armor plate, proving that air-launched weapons could defeat hard, mobile targets.

Bombardment Aircraft Rocket (BOAR)

The BOAR was a 30.5-inch rocket-propelled nuclear ballistic standoff weapon. It was designed to be deployed by high-performance aircraft in a low-level loft-and-escape maneuver—a technique developed by VX-5 at China Lake. Essentially, the aircraft released the weapon in a steep climb to maximize the weapon's range, at which point the motor would ignite and the aircraft would quickly turn to put as much distance between itself and the imminent nuclear explosion. Deployed in 1956, BOAR was one of the earliest rockets designed to carry a nuclear warhead, and, apart from the nuclear components themselves, China Lake was responsible for the entire system, including the automatic weapon-release computer used in the special launch technique. [144]

Spin-Stabilized Bombardment Rocket (SSBR)

Another heavily used rocket developed by China Lake was the SSBR. Fired from both land and water surface vehicles, these rockets were designed for surface-to-surface area neutralization and fire support. As the name implies, spin-stabilized rockets use a spinning motion, as opposed to fins, to stabilize the rocket during flight. The reasoning behind this is twofold: first, unlike air-launched rockets, surface-launched rockets have no initial airspeed that renders fin stabilization ineffective; second, spin-stabilized rockets can be shorter in proportion to diameter size. These rockets were used in such great numbers and with such great success in World War II and the Korean War that China Lake was tasked with improving the range and effectiveness of the rocket for the impending conflict in Vietnam. The result

was the Bombardment Rocket, a new rocket capable of striking a target 18,000 yards away with the same lethality as previous 5,000-yard-range rockets.

Shrike/High-Speed Anti-Radiation Missile (HARM)/ Advanced Anti-Radiation Guided Missile (AARGM)

Shrike

The AGM-45 Shrike is a passive-homing air-to-ground ARM designed to suppress enemy air defense. It was the first U.S. ARM to be mass produced. Beginning in 1958, China Lake conceived, designed, developed, and tested Shrike as a direct response to Fleet needs. Most notably, China Lake pioneered anti-radiation guidance employed by Shrike and its successors: the AGM-88 HARM and the AGM-88E AARGM. China Lake also assembled a dual-source production data package to establish competition, a decision that resulted in significant savings. [30]

During the Cuban Missile Crisis in 1962, China Lake was called upon to produce 200 Shrike missiles, which, at the time, were still under development. With assistance from Texas Instruments, China Lake was able to meet the demand in just slightly more than 6 months, building half of the missiles in house. Shrike officially entered service in 1965 and served the U.S. Navy and Air Force well during the conflict in Vietnam. During that same time, China Lake completed another quick-response project by adapting the Shrike to shipboard launch, creating the Shrike-on-board system. [141]

Shrike had two major limitations: first, it had to be pointed toward the desired target; second, the target had to continue to radiate or Shrike would lose its lock on it. Therefore, China Lake continued to develop anti-radiation technology, which led to the next-generation ARM, HARM. [206]

High-Speed Anti-Radiation Missile (HARM)

The HARM was designed to address the deficiencies in Shrike and to incorporate new technologies to engage modern, constantly evolving threats. For that reason, HARM is constantly being updated. The first improvements to HARM consisted of a broadband antenna, programmable software, a new seeker with the ability to handle a wider range of frequencies, a new motor with a longer range, and an improved warhead. This version of HARM, designated AGM-88A, was released in 1983 but was replaced by the AGM-88B only 3 years later. The AGM-88B introduced the ability to rapidly change software on the flight line, a major operational advantage over the AGM-88A, which had to be returned to the depot for software changes. In 1991, the Fleet received the AGM-88C, which had a new seeker with the ability to counter frequency-agile targets and a new warhead capable of engaging hardened

structures. The release of new HARM variants often ran in parallel with the release of new software upgrades; thus, AGM-88A received Block I and II, AGM-88B received Block III, and the AGM-88C received Block IV and Block V. [204]

NAWCWD remains the technical lead for HARM and is responsible for legacy HARM software updates. The ARM TPO continues to develop the Block 5A software upgrade and, in 2008, released the HARM User Data Files/Electronic Intelligence 503 file, further increasing HARM lethality. The ARM TPO Fleet Support Program continues its HARM University program, in which U.S. Navy, Marine Corps, and Air Force aircrew receive graduate-level training in suppression of enemy air defense (SEAD). [54] [172]

The HARM has seen consistent combat since its introduction. It was first used in combat in Libya in 1986, was used during Operation Desert Storm and Operation Just Cause, and is still in use today in support of the War on Terror.

Advanced Anti-Radiation Guided Missile (AARGM)

The AARGM is an enhancement kit for the HARM and is the next-generation ARM. The kit mates a completely new dual-mode anti-radiation homing and millimeter wave terminal guidance section and a modified control section with GPS/INS capability to the rocket motor, airframe, and warhead of an AGM-88B/C. NAWCWD served as the lead technical field activity, as well as the lead for T&E in captive and live fire scenarios. AARGM passed its preliminary design review in 2005 and critical design review in 2006. Developmental Test 1 (DT-1) took place in 2007 at NAWCWD's ranges. DT-2, DT-3, and DT-4 took place in 2008, leading to low-rate initial production. In 2009, China Lake completed the remaining developmental tests (ending the system development and demonstration phase) and began operational evaluation (OPEVAL) in preparation for the planned initial operating capability in late 2010. [172]

Standoff Land Attack Missile (SLAM)

The AGM-84E SLAM is a standoff-outside-area-defense air-to-surface missile. Its primary targets include high-value/time-critical land targets in high-threat areas and ships in port. SLAM was designed around the AGM-84D Harpoon by using the IR seeker from an AGM-65D Maverick, the video data link from AGM-62 Walleye, and a GPS receiver. SLAM entered service with the U.S. Navy in 1990 and is still operational today. [204]

NAWCWD wrote the system specification and statement of work for the initial concept of SLAM and was involved in all engineering efforts from conception through full-rate production. Even though SLAM was still undergoing OPEVAL at Point Mugu, it was sent to support the Warfighter in Operation Desert Storm. All told, seven SLAMs were launched at high-priority targets in support of that effort. The images from these engagements were shown on national television. [136]

As a result of SLAM's performance during Operation Desert Storm, a program was initiated to increase SLAM's capabilities. NAWCWD played a key role in this effort by developing a new warhead with better penetration and lethality, as well as improving its ability to meet new IM requirements. NAWCWD also supported developmental and operational testing; developed, acquired, and loaded government-furnished equipment warheads and fuze boosters; developed new all-up-round software; and provided system engineering. These efforts led to initial operational capability of the AGM-84H/K Standoff Land Attack Missile–Extended Response (SLAM-ER) in 2000. With that release, SLAM-ER became the U.S. Navy's primary standoff-outside-area-defense weapon. In 2005, NAWCWD achieved another milestone with SLAM-ER when the CLPL completed the 500th successful SLAM-ER warhead. All 500 warheads were delivered on schedule, within budget, and without significant defects. [177]

The SLAM-ER received another upgrade with the automatic target acquisition system. A missile with this capability was successfully fired on the test ranges at China Lake before becoming operational in 2002. In 2009, the SLAM-ER TPO completed a Rapid Technology Transfer Program, adding a land moving target capability to the SLAM-ER, and proved the weapon's effectiveness with a direct hit on a moving land target. [172]

Like its predecessor, the SLAM-ER was called into duty at the outbreak of conflict following the events of September 11, 2001. Within weeks of that incident, NAWCWD personnel loaded upgraded software into SLAM-ERs headed for the Persian Gulf aboard USS *John C. Stennis* in support of the War on Terror. [71]

Surface-to-Surface Missiles

Antisubmarine Rocket (ASROC)

After World War II, the Navy sought a means of extending the range of antisubmarine warfare (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 into the ASROC Program.

The ASROC is a quick-reaction all-weather intermediate-range 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. The system became operational in 1961 and was used frequently during the Vietnam conflict.

In 1964, China Lake upgraded the ASROC to double the missile's standoff range and increase its delivery accuracy. In the early 1970s, advances in sonar technology enabled ships to detect targets far beyond the range of the ASROC. The Navy's response was to develop the Vertical Launch ASROC (VLA), an effort in which China Lake would act as the key developer. China Lake had already conducted the QuickTurn/Agile Programs, which demonstrated advanced threat reactor control airframe controllability during the late 1960s and early 1970s. The VLA is an improved rocket-propelled ASW weapon that is designed for deployment on ships equipped with the Mk 41 Vertical Launching System. The VLA uses a larger rocket motor with a jet vane thrust vector control system and an onboard 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. China Lake was also responsible for developing and testing the autopilot, staging system, rocket motor, and the thrust vector control system for the VLA project.

By the mid-1970s, China Lake efforts had resulted in two vertical rail launches of modified ASROC airframes with thrust vector control. 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. The formal VLA Development Program was then initiated, and VLA missiles were introduced to the Fleet by 1993. The China Lake thrust vector control technology also provided the basis for numerous advancements in other weapon systems, such as the Tomahawk and Standard Missile.

VLA has replaced the ASROC in the United States and in several allied countries that also use the vertical launching system. Although the U.S. Navy ended production in 1993, the system is still being actively procured by allied foreign governments. In addition, NAWCWD 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 and the ESSM. Thrust vector control technology is also an important part of the Standard Missile-3 Third-Stage Rocket Motor, a key element in the Navy's Sea-Based Theater Ballistic Missile Defense Program. [13]

Fleet Ballistic Missiles

Responding to a growing Soviet nuclear threat in the 1950s, the United States began developing intermediate-range ballistic missiles. Fleet ballistic missiles are large long-range submarine-launched missiles equipped with nuclear warheads. China Lake's development efforts advanced thrust vector control systems, propellant efficiency and safety, and technology for large rocket motors. Although these missiles were never fired in combat, the early China Lake studies had a profound effect in shaping the country's strategic deterrence policies, thus contributing to international stability.

Polaris

The Navy realized that the Army's Jupiter missile, the original SLBM, was too large and heavy for shipboard use and its liquid fuel was too toxic. China Lake, working with the Bureau of Ordnance, developed the concept of using a small solid-fueled rocket motor to launch a missile from a submarine. After feasibility studies, component tests, fuzing and rocket motor tests, and full-scale underwater launch programs were conducted, analysis suggested a smaller warhead and a newer reentry body concept were needed. Polaris was the result. The UGM-27 Polaris was a solid-propellant SLBM that had two stages of propulsion. Polaris A-1 weighed 28,800 pounds and had a range of approximately 1,000 nautical miles.

The Eisenhower administration accelerated Polaris deployment, a decision that resulted in the first successful underwater launch of a Polaris A-1 from USS *George Washington* in 1960. In 1962, USS *Ethan Allen* launched a Polaris, which flew 1,700 miles and detonated. This effort represents the only U.S. intercontinental ballistic missile (ICBM) test with a live nuclear warhead. In 1969, the Navy began to convert the Polaris submarine fleet to the larger Poseidon C3 missiles. China Lake continued to provide T&E support for Polaris throughout the life of the program until the conversion was complete.

Overall, the Polaris Program was 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.

Poseidon

In 1965, the Poseidon was developed as an update to the Polaris missile. The Poseidon weighed 65,000 pounds, could deliver a much larger payload with greater accuracy, and was the first to carry a multiple independently targetable reentry vehicle (MIRV) payload of up to 14 small reentry vehicles.

China Lake's studies strongly influenced Poseidon's design and hardware, and China Lake tested the Poseidon motors throughout the project. 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, and the Poseidon missile program ended in 2003.

Revolutionary Approach to Time-Critical Long-Range Strike (RATTLRS) Program

The RATTLRS effort is a Navy-led flight demonstration project to develop advanced technologies for turbine-powered expendable flight vehicles that can travel at supersonic speeds exceeding Mach 3. The RATTLRS concept involves a highly integrated supersonic air vehicle with an inlet and nozzle system. This weapon incorporates an expendable turbine propulsion system, whose size, shape, and weight are traceable to a joint tactical expendable weapon system. NAWCWD is tasked with the chief engineer functions, tactical weapons traceability, aeromechanical design support, flight test planning, and flight range supporting operations.

The flight tests demonstrated a subsonic launch and high acceleration rate in climbing flight without a booster to a Mach 3.0+ cruise speed for up to 15 minutes. The RATTLRS Program also supports and leverages the technology development efforts of the Air Force and NASA in high-speed vehicles and turbine-based propulsion systems.

The program completed its critical design review in 2006 by successfully completing a 500-pound warhead penetration test at Holloman AFB, New Mexico. During this test, the RATTLRS forebody flew straight and level from the end of the track and hit the target (reinforced steel rebar concrete blocks) nearly directly on center at an impact velocity of Mach 2+. NAWCWD continues T&E efforts, and the RATTLRS flight test program is being completed.

Regulus

Regulus was developed in the late 1940s to meet the Navy's requirement for a long-range submarine-launched bombardment weapon. Regulus I was a 500-mile-range surface-to-surface subsonic guided (cruise) missile that began testing at Point Mugu in 1949. The Regulus II had a range of 1,380 miles and was initially boosted by a rocket motor and then powered by a 10,000-pound-thrust turbojet engine to a speed of Mach 2.

Regulus came to Point Mugu for T&E in January 1949 and became the largest single program in Point Mugu

history in terms of manpower and facilities. Some of the first testing was conducted at San Nicolas Island, and the first submarine launch was made from USS *Tunny* in 1953. Regulus II became operational in 1955 and was the Navy's first supersonic cruise missile with a capability of delivering a nuclear warhead. It was successfully launched in 1958 from the submarine USS *Grayback*, but the Regulus Program was canceled soon after that launch in favor of the Polaris Program. After 1958, the Navy used the remaining 54 Regulus II cruise missile as supersonic target drones, equipping them with landing gear. Most of the Regulus II drones were used at Point Mugu, where 17 target drones made 64 flights. The last Regulus II target drone was flown in 1965. [50] [136]

Trident

In the 1970s, the Navy developed the Trident missile, which provided the Underwater Long-Range Missile System with a larger, more-accurate missile. Selected in 1975 to build a Trident SLBM operational test range in the Pacific, Point Mugu designed and installed the Trident Missile Test Instrumentation System, which was the most complex and extensive range system ever assembled at Point Mugu. The system became operational in 1983 and provided test forces with real-time range safety displays, underwater submarine tracking, in-flight tracking of up to four missiles, instantaneous impact predictions, and recording and display of missile telemetry.

The Navy moved ahead with plans for the larger, more-accurate Trident II in 1983. The Trident II D-5 is a three-stage inertially guided solid-propellant missile and has a range of more than 4,000 nautical miles. After 15 of 18 successful land firings in the first underwater launch in 1989, the missile experienced flight control failure and was commanded to self-destruct. China Lake was assigned the task of failure analysis of the missile. Design improvements were then made based upon China Lake's recommendations, and the missile has never again malfunctioned.

In 2005, NAWCWD was very active in the Trident Fleet Missile project, conducting critical experiments to assess the feasibility of inserting advanced propellant, case, insulation, and test/instrumentation technologies into the Trident Post Boost Control System. Sea Range personnel coordinated with the Reagan Test Site in the South Pacific, PMR, Vandenberg AFB, and two dedicated instrumentation support ships to conduct SLBM tests from a Trident submarine. [172]

China Lake continues to evaluate the Trident propellant aging properties to help the Navy understand the quality and reliability of the Trident weapon inventory. For example, NAWCWD helped develop technology to contain and scrub exhaust during motor destruction to emit only

carbon dioxide and water. This demilitarization technology was a first, and it resulted in the full-scale Modified Contained Burn Assessment Test Facility, which successfully demonstrated 98+% removal efficiencies on full-size 20,000-pound motors; this achievement ensured that the program would meet strict Strategic Arms Reduction Treaty (START) requirements. [204]

China Lake is also involved in the Trident D-5 Service Life Extension Program, which seeks to find alternative sources of supply and qualify new component production methods. Throughout the entire Fleet ballistic missile program, China Lake has tested more than 500 motors.

Harpoon

In 1965, the U.S. Navy began studies for an antiship missile. By 1971, McDonnell Douglas was awarded the contract to develop Harpoon, and China Lake was designated as the lead field activity providing technical production and logistics support. 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. 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 and industrial facilities.

Working with industry, NAWCWD also developed and improved the warhead's fuze, as well as the SAD. China Lake improved the IM capability of Harpoon, and Point Mugu developed the cast glance high-altitude photography capability to support Harpoon tests. The Block II upgrade incorporates elements of the JDAM and the SLAM-ER and uses GPS-aided inertial navigation to hit a designated aimpoint. Harpoon was first used in combat in 1984 against Libyan missile ships in the Gulf of Sidra.

During 2000 through 2001, NAWCWD supported Harpoon Block II improvements, and Point Mugu demonstrated Block II upgrades on the Sea Range by using the Mobile Ship Target (MST). NAWCWD has a role in the development and engineering, T&E support, software integration, and Fleet logistics for Harpoon. NAWCWD works with industry to ensure the quality of the warhead and fuze package and 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. In 2009, the Harpoon Block II was successfully fired from USS *Princeton* in support of the Guidance Control Unit (GCU) Obsolescence Program. This firing proved the readiness and suitability of a GCU that is compliant with the Harpoon's Selective Availability Anti-Spoofing Module. [204]

Although the U.S. Navy orders ceased, Harpoon upgrades will continue to 2015. The missile also continues to be one of the most widely exported Navy weapon systems, with more than 30 allied nations fielding the system. [20]

Joint Multi-Effects Warhead System (JMEWS)

The JMEWS is a long-range weapon system that provides increased flexibility and lethality in denied environments against hardened targets. This warhead technology will provide a leap-ahead capability against a widely varied target set, which includes hard and soft targets. In concert with the in-flight targeting system, JMEWS allows dynamic targeting and re-tasking of the missile as intelligence is updated. For example, with JMEWS, a missile may be configured to destroy a hard target but, in flight, could be redirected to a soft target, a capability that requires a different type of explosive.

Currently, the JMEWS warhead is being integrated into a Block IV Tomahawk missile because the warhead's extended operating range and in-flight command and control are critical to successfully mitigating identified capability gaps. The JMEWS warhead will require extensive weapon system integration with the Block IV missile and will influence areas such as the weight and balance, guidance and control, executive computer control software, and the missile's satellite data terminal.

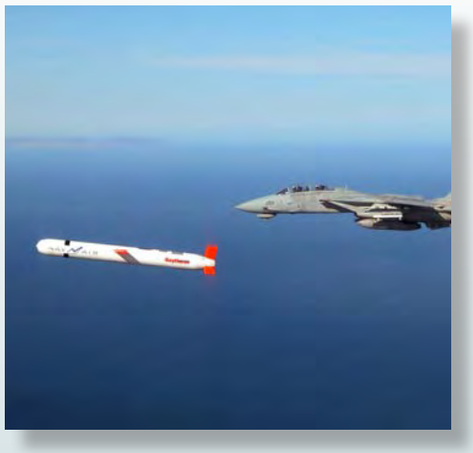
NAWCWD China Lake is the Navy's lead T&E agent on the JMEWS project, and Raytheon was awarded an advanced technology study contract in 2009 to perform engineering and analysis on the integration. NAWCWD provides fuzes and technical support, and its ranges will help support JMEWS flight tests. Integration and full-system test demonstration are required within 3 years. The production warhead is tentatively scheduled to be introduced to the Fleet in 2014/2015.

Other platforms may be considered for future follow-on acquisition after the JMEWS warhead design is optimized and successfully flight tested. [172] [204]

Tomahawk

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 subsonic 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 RCS and low-altitude flight. IR detection is difficult because the turbofan engine emits little heat. Tomahawk has an inertial and terrain contour-matching radar guidance system that uses a stored map reference onboard 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.



There have been several variants of the Tomahawk, employing various types of warheads. For example, the Tomahawk Land Attack Missile/Nuclear (TLAM-N) had a W80 nuclear warhead, the Tomahawk Antiship Missile was a radar-guided antiship variant, and the Tomahawk Land Attack Missile/Conventional (TLAM-C) had a unitary warhead.

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 the first submarine launch was made off Point Mugu in 1978. During this time, Point Mugu developed the cast glance high-altitude photography system that supported Tomahawk tests. In the early 1980s, China Lake became the principal support laboratory and applied thrust vector control steering to Tomahawk. In addition, NAWCWD developed a second production source (dual source) for the missile, thus resulting in improved reliability and a significantly reduced unit cost. NAWCWD was also the deputy program manager for the rocket motors, managing the rocket motor design and procuring the units for the Tomahawk All-Up Round Program Office. For the Block III upgrade, NAWCWD developed a new lightweight warhead and fuze. Tomahawk initial operational capability was achieved in 1983.

Tomahawk's first operational use was in 1991 during Operation Desert Storm, and the weapon was immensely successful. 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. For example, during Operation Iraqi Freedom, the Navy launched 802 BGM-109 Tomahawks. On the first night of major air operations, more than 100 Tomahawk missiles crippled Iraq's air defenses by eliminating the high-power, low-frequency radars that surrounded Baghdad, as well as destroying SA-2 and SA-3 sites and airfields throughout Iraq.

During 2000 and 2001, NAWCWD supported three major efforts, including the Tactical Tomahawk, the Tactical Tomahawk Penetrator Variant for deep targets, and Block II/III upgrades. China Lake was the Navy's principal support activity for the Tomahawk, the acquisition engineering agent for the all-up round, and the software engineering agent and the engineering design agent for

the Tactical Tomahawk Penetrator Variant warhead. In 2002, a Tomahawk was launched in an 860-mile successful test flight from the submarine USS *Bremerton* submerged on the Sea Range. The NAWCWD/Raytheon Tactical Tomahawk team conducted the first free flight of Block IV, demonstrating in-flight retargeting and ultrahigh frequency satellite communications. The Tactical Tomahawk team later demonstrated in-flight retargeting, the loiter and battle damage assessment capability, and mission planning onboard the launch platform and provided in-flight health and status reports. The team also developed the Tomahawk In-Flight Missile Simulator (TIMS) Pod and integrated it onto the F/A-18, efforts that greatly reduced testing costs for missile updates. [35]

In 2004, the Tomahawk's network centric warfare capabilities were upgraded to use data from multiple sensors (i.e., aircraft, UAVs, satellites, tanks, ships) to find the target and to send data from that weapon's sensors to these platforms or the warfighter commander. This version was named the Tactical Tomahawk. The Tactical Tomahawk is also equipped with a television camera to observe the battlefield, thereby allowing warfighter commanders to assess target damage and redirect the missile to an alternative target. The Tactical Tomahawk has an additional feature that allows it to be reprogrammed in flight to attack 1 of 16 predesignated targets stored in its memory or to attack any other GPS coordinates. [204]

A demonstration was performed in 2009 that allowed Special Operations Forces to designate, plan, and call for fire using a Block IV Tomahawk. This test demonstrated how the Tomahawk has become a key enabler for time-critical strikes and is an invaluable asset to the Warfighter. In 2010, USS *Cheyenne*, in conjunction with Commander, U.S. 7th Fleet, and members of the Naval Special Warfare Group (NSWG), successfully fired a Block IV Tomahawk Land Attack Missile into the China Lake test range. This test was the first time a forward-deployed operational command acted as the Tomahawk strike coordinator and primary missile controller for an operational test and proved that real-time targeting coordinates can be applied to the missile in flight. NAWCWD China Lake continues formal government testing of the Tactical Tomahawk's capabilities from surface/subsurface launch platforms. [172] [204]

Surface-to-Air Missiles (SAMs)

Bumblebee

The Bumblebee effort represented a significant post-war missile test series designed 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.

China Lake and Point Mugu conducted numerous tests on the Bumblebee in the late 1940s. Between 1945 and 1952, a swarm of Bumblebee missiles flew over China Lake. In 1947, the first successful subsonic beam-riding flight was made at China Lake when a roll-stabilized control test

vehicle followed a fixed radar beam for 16 seconds. A historic milestone in guided missile development was achieved in 1948 when two successful supersonic beam-riding flights were conducted at China Lake. These tests were the world's first successful beam-riding flights at supersonic velocities. [29]

Lark

Lark was a radio-controlled surface-to-air subsonic missile intended for shipboard launch against aircraft. Lark was 14 feet long, 17 inches in diameter, and was powered by a liquid propellant rocket engine. The Lark was designed to be launched by two strap-on 1,000-pound-thrust jet-assisted-takeoff units and then to be 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 1948, all Lark testing was shifted to the NAMTC at Point Mugu, where the Lark achieved a number of significant firsts in radar guidance. In one test, guidance was provided by two antiaircraft radars; one maintained line of sight directly 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.

In 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 after that test, a Lark successfully guided toward an aircraft using an optical missile and target tracking system and then employing an automatic electronic command signal computer that derived intelligence from an optical tracking device. In 1951, a Lark fired from Point Mugu made the first guided missile "kill" against an airborne target, scoring a direct hit on a radio-controlled drone. This test was significant because previous kills had been a result of the missile merely passing within lethal range. [50]

Phalanx

In the 1970s, NAWCWD conducted T&E for the Phalanx. The Mk 15 Phalanx Close-In Weapon System 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. This weapon 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, added

two new missions: anti-surface warfare to combat small boat threats and antiair 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-millimeter ammunition at either 3,000 or 4,500 rounds per minute.

General Dynamics completed the first production model in 1979, and the first Phalanx systems entered service in 1980. Phalanx was subsequently fitted on all surface warships of at least frigate size, all major amphibious warfare vessels, and all combatant ships of 20 allied nations. A Block I upgrade entered service in 1988 and was capable of dealing with high-angle diving threats. The weapon system has steadily evolved since 1988, with NAWCWD continuing to support T&E on its Land and Sea Ranges. NAWCWD conducts aircraft tracking exercises for software development using various avionic platforms, including F-86s, A-4s, F/A-18s, Cobras, Lear jets, and Iskras. [26]

Rolling Airframe Missile (RAM)

The RIM-116A RAM is a lightweight, quick-reaction, high-firepower surface-to-air weapon designed to counter antiship missiles. The RAM is a 5-inch passive dual-mode RF and 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 supplements Phalanx and SeaSparrow in the ship's defensive arsenal. The RAM system has been installed onto more than 80 United States Navy, 28 German Navy, and 3 Korean ships.

The RAM started as a joint United States and German venture, with China Lake as the United States Government's lead technical agent for development. Initial development began in 1974, and production was initiated in 1987. In 1990, 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 reliable, another test firing sequence began. This time, the missile worked flawlessly and received approval for full-rate production, and, in 1992, the first ship was fitted with RAM.

In 2000-2001, NAWCWD served 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 simulation, performed concept studies for product improvement, and supported extensive missile testing. In 2004, China Lake designed the first full-scale boost–sustain solid rocket motor with advanced composite casing, a major breakthrough.

China Lake simulations are accredited for preflight and postflight test predictions and comprehensive performance analyses against current real-world cruise missile threats. NAWCWD is also responsible for IR measurement and IR model development to support simulation. In addition, China Lake is the design agent for developing the rocket motor for the RAM Block II kinematic upgrade design. In 2008, it was determined that the upgrade design was ready for implementation, integration, and verification. The NAWCWD Sea and Land Ranges continue to be used for operational and development testing. [28]

RAM has been fired in more than 150 flight tests to date, with a success rate greater than 95%. A capability against helicopter, aircraft, and surface targets is currently being developed, and operation evaluation occurred in 2005. SeaRAM is also being developed for smaller ships, and, in 2008, a SeaRAM system was installed on USS *Independence*. [172] [204]

SeaSparrow

The SeaSparrow SAM system, which was based on the original air-to-air Sparrow missile, can destroy hostile aircraft and antiship missiles. The first shipboard launch took place in 1972, and a vertical launch system was tested in 1981. 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 an active radar fuze. Twelve NATO nations are involved in the program. The AIM/RIM-7P began development in 1987, and deliveries of SeaSparrow began in 1991. The SeaSparrow has a low-altitude guidance system that is effective against very-low sea-skimming cruise missiles.

Since 1991, NAWCWD has served as the technical direction agent on the SeaSparrow Program. By 1995, engineering and manufacturing on the ESSM began. The ESSM was a kinematic improvement to the SeaSparrow, with a primary mission of destroying highly maneuverable low-altitude antiship cruise missiles. The missile incorporated midcourse data links to provide ship-based corrections during flight. RIM-162 ESSM entered low-rate initial production in 2003, with NAWCWD continuing T&E.

In 2006, NAWCWD investigated backfitting the ESSM's warhead into SeaSparrow. As the technical design gent for ESSM, NAWCWD has supported the development of a new radome, front receiver, warhead fairing, telemetry system, control section, and rear receiver. NAWCWD was the lead in pioneering and developing the surface-to-surface guidance improvements for SeaSparrow, and the ESSM software was completed in 2006. Since 2007, NAWCWD has worked on unique software algorithms for engaging multiple targets using SeaSparrow. In addition, several

T&E events were supported in 2009, including scenario development, flight test predictions, and post-flight support. [172] [204]

Spike

Spike is a man-portable fire-and-forget guided missile and launcher system that is very low cost and lightweight. Highly effective against helicopters and lightly armored vehicles, Spike is a boon to warfighters in urban assault scenarios because it is light and easy to fit into a backpack (e.g., fitting up to three missiles) and because the missile can travel through a window before exploding.

Originally conceived and developed at China Lake, Spike is the smallest guided missile in the world, at 25 inches in length and 2.25 inches in diameter, with a weight of 5.3 pounds. It is the only missile using an electrooptical imaging strapped-down seeker. 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 antitank missile. Compared to unguided RPGs with a range of only a few hundred yards, Spike has a range of approximately 2 miles. The cost of a Spike missile is also significantly less than that of the Javelin missile, thereby allowing the more costly missile to be used for heavily armored targets. The cost goal of $5,000 per unit makes Spike the lowest-cost guided missile in existence.

In early 2009, Spike was fired from a UAV. The test used the NAWCWD-developed UAV-capable Airborne Fire Control System (AFCS) for the first time. Test engineers fired Spike from the top of a small mountain, with the missile hitting a moving target on the valley floor nearly a mile and a half away. Spike was also successfully launched in mid-2009 onboard the U.S. Army's Vigilante vertical takeoff unmanned aerial vehicle (VTUAV). These tests demonstrated Spike's ability to acquire and track targets while being remotely operated. Further T&E are continuing. [172] [204] [219]

Standard Missile

Standard Missile 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, the Bumblebee. The newer Standard Missile concept minimized compatibility changes and was modular in design for ease of upgrade. Standard Missile began development in 1964, entered service in 1968, and has steadily evolved. The three main subtypes included the Standard Missile-1, Standard ARM, and Standard Missile-2.

China Lake is both the design agent and technical direction agent for all Standard Missile fuzing (target-detecting device [TDD], SAD, and fuze contact device) and portions of the flight termination system in the Standard Missile-1 and Standard Missile-2. The China Lake-developed Mk 45 TDD for Standard Missile is considered by many to be the world's premier missile fuze.

A variant of Standard Missile, the AGM-78, was developed in 1968 as an air-launched version of the Standard Missile-1 to extend the range of the Shrike missile. During the Vietnam conflict, an immediate need arose for a specialized TDD for Standard ARM. In only 8 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 Air Force used Standard ARM extensively to destroy North Vietnamese radars that controlled antiaircraft guns and missiles.

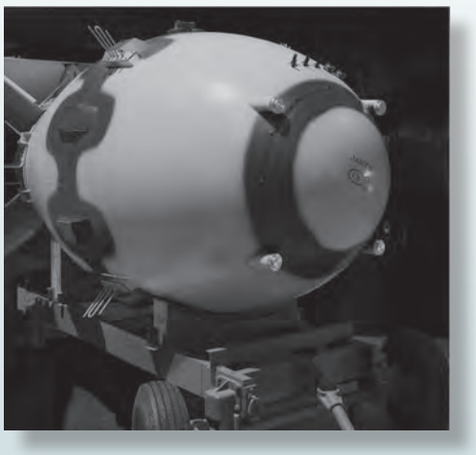
The Standard Missile-2 Block I was an all-weather ship-launched medium-range air defense missile with added midcourse command guidance to increase area coverage. In the Standard Missile-2 Block II effort, which began in 1977, a new ordnance package and propulsion upgrade were added. Standard Missile-2 Block IIIB included an adjunct IR seeker, and Block IV is a longer-range version using a booster for launch. NAWCWD helped develop the Mk 45 Mod 9 and 10 TDDs, the Mk 54 SAD, and the Mk 5 fuze contact device used in Standard Missile.
NAWCWD is the technical direction agent of the NAVSEA for the Mk 45 Mod 9, 10, and 14 TDDs and the technical direction and design agent for the SAD, arm-and-fire device (AFD), and fuze contact device. China Lake maintains a computer-in-the-loop facility for software development and TDD tests. NAWCWD developed and maintains a new engineering simulation, GENSIM, used to predict the performance of the Mk 45 TDD. NAWCWD conducted blow-down wind tunnel tests to qualify the Mod 9, 10, and 14 TDDs. For the cancelled Standard Missile Block IVA Program, NAWCWD developed an accurate method of field testing forward-looking fuzes by using artillery shells as targets and provided consultation on IR seeker development. NAWCWD is also funded to develop new safety and arming technology using microelectromechanical systems (MEMS) technology. [172] [204]

NAWCWD also supports the development and testing of the Standard Missile-3, a variant of the Standard Missile that fires from an Aegis cruiser to intercept a ballistic missile in the exo-atmosphere. During 2002, NAWCWD participated in three successful flight tests at the Pacific Missile Range Facility (PMRF) in Kauai, Hawaii, successful events that resulted in the first-ever sea-based ballistic missile intercepts.

NAWCWD supports development of the Standard Missile-3 with sea-based kinetic-energy boost-phase intercept missile technology. China Lake worked on the kinetic warhead, the third-stage rocket motor, and axial propulsion. More than 20,000 Standard Missiles have been produced and exported to more than a dozen countries. NAWCWD is also involved in development planning and contract formulation for the Standard Missile-6 Program.

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 end World War II. China Lake was a major contributor to the success of those weapons. The United States initiated a program in 1942 under the Army Corps of Engineers to build a weapon that would allow the United States 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 carried out Project Camel, the code name for China Lake's involvement in the Manhattan Project.

The deadline for building at China Lake was set: less than 4 months in which to construct 80 buildings (52 permanent) and for operations to begin 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/her work by two heavy concrete walls. All buildings were designed to hold a temperature tolerance of ±2°F. 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 9 days after the test of the world's first nuclear weapon at Trinity Site, New Mexico.

An atomic bomb is essentially a conventional bomb with a nuclear core. The China Lake and the Caltech Team were tasked to develop the nonnuclear explosive components of the atomic bomb and the conventional explosives 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 aeroballistic tests to optimize aerodynamics and to test fuze functions. The team also evaluated equipment procedures to be used in the tactical delivery of the atom bomb.

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.

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 in case Fat Man or Little Boy was jettisoned at sea.

With the materials and equipment shipped to China Lake for Project Camel, 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.

On August 6, 1945, the Little Boy uranium-based atomic bomb was air dropped over Hiroshima, Japan, and 3 days later, Fat Man, an implosion-type plutonium-based atomic bomb, destroyed Nagasaki. As mentioned, China Lake was instrumental in the development of the nonnuclear components and the conventional explosives necessary for both types of bombs to work.

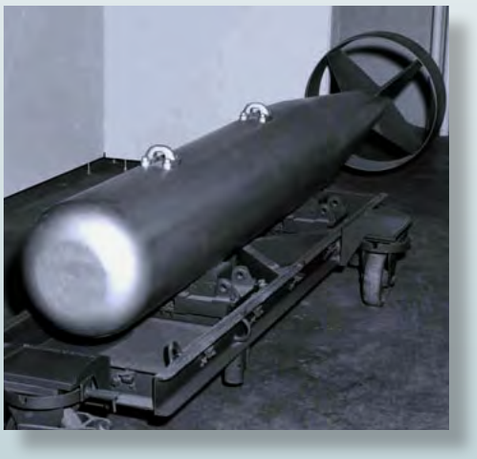
In 1946, the Salt Wells Pilot Plant at China Lake was ordered to step up production. Because Salt Wells was the single source for high-explosive components of the fission-type bomb, no other such facility had been built. Through the mid-1950s, China Lake continued to be a major producer of certain chemical 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.

From 1951 through 1953, 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. These VX-5 officers and about 100 enlisted men tested and perfected the 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 10,000 Mk 76 practice bombs.

Many of the original buildings used in the atomic bomb work at China Lake are still standing and have been nominated to be included on 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.

Mk 8 Elsie

In the early 1950s, China Lake redesigned the Elsie (TX 8/TX 11), an experimental nuclear-penetrator weapon. Only one flight test was conducted, with the effort suspended in 1955 when the Navy decided to investigate the thermonuclear warheads for Regulus. Elsie was reported to be able to penetrate 22 feet of reinforced concrete, 90 feet of hard sand, 120 feet of clay, or 5 inches of armor plate before detonating. [222]



“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, 1945

Weapons–Platform Integration

Weapons–Platform Integration

NAWCWD provides weapon integration support on fixed-wing, rotary-wing, and unmanned platforms, like the F/A-18, EA-18G, EA-6B, AV-8B, F-22, F-35 JSF, AH-1, UH-1, AH-1Z, and others. NAWCWD pioneered the systems approach to weapon integration, which incorporates integration processes early in the design and developmental stages of aircraft and weapon systems. Before this method, the weapon system and aircraft were developed separately and integration of the two was conducted after the fact. Weapon–platform integration work at NAWCWD covers the entire gamut of weapons, avionics, and platforms, including those systems used in EW. However, because that specific mission is covered elsewhere, this section will focus on more-conventional weapons, avionics, and platforms. Nonetheless, examples taken from the F/A-18, AV-8B, H-1, and others will emphasize the scope of NAWCWD's involvement in this area and provide a clear picture of the benefit the Fleet derives from this work.

Bomb Racks and Missile Launchers

Two elements vital to the integration process in which NAWCWD continues to make great progress are bomb racks and missile launchers. One of the most important developments in this area is the BRU-69/A Multipurpose Bomb Rack (MPBR) for the F/A-18 and JSF. This bomb rack is the first totally new bomb rack by the U.S. Navy in 40 years and will replace the BRU-33, BRU-41, BRU-42, and BRU-55 racks. The rack is equipped with a new universal armament interface that allows it to work with current and future PGMs, as well as with conventional iron bombs, practice stores, and pyrotechnics. As is the trend, the BRU-69/A will allow attack aircraft to carry two PGMs per station, thus reducing the number of missions flown and mitigating the pilot's exposure to adverse threats. The BRU-69/A also features a non-pyrotechnic ejection power source that will increase mission reliability and reduce maintenance requirements. In 2009, the system entered Milestone B (system design and demonstration) and is on schedule for Fleet release in 2017. In the meantime, NAWCWD will continue to upgrade existing bomb racks to provide the Warfighter every advantage possible. For example, in 2009, the BRU-55/A Smart Multiple-Carriage Bomb Rack, an updated version of the BRU-33/A that allows attack aircraft to carry two PGMs per station, was released to the Fleet. Work is also under way to upgrade the BRU-61/A SDB Rack to provide carriage of the SDB II on the F/A-18E/F and JSF. Lastly, in 2009, an initial production order was placed for the new AIM-9 missile launcher for the F/A-18A through F/A-18D's wingtips. This new launcher incorporates previous upgrades such as the pure-air generating system; digital power supply; and AIM-9X fin retainers, with a higher-strength rail material with new geometry for improved fatigue life; one-piece forward and aft fairings; and a low-cost power supply. [172]

F/A-18

The F/A-18 is a multirole carrier-capable supersonic strike aircraft capable of air-to-air dogfights and air-to-ground target attacks, thus the designation fighter/attacker. The F/A-18 forms the core of the Navy's air warfare capability and, as such, has been upgraded several times since its introduction to the Fleet in 1983. The latest variant, the F/A-18E/F (F/A-18E is the single-seat variant and the F/A-18F is the two-seat version), has 11 weapon stations that can accommodate 29 configurations, thereby making weapon–platform integration vitally important. [204] [207]

To successfully integrate weapon systems, subsystems, and the associated software, NAWCWD built the F/A-18 AWL and staffed it with experts from both government and industry. NAWCWD has been instrumental in integrating various systems in the F/A-18, including weapons such as the Sidewinder, the JDAM, and AARGM, as well as radar and communication systems like the AESA radar and SHARP. Developing software to work with all these systems is a particularly daunting task, especially given the fact that the F/A-18 has more than 40 processors and more than 10,000,000 words of code, but NAWCWD performs the task exceptionally well. As a result of this excellence, the Software Engineering Institute awarded the AWL its Level 4 rating, putting it in the top 9% of software developers in the world. NAWCWD also helps integrate weapon systems (both foreign and domestic) on allied F/A-18s, including the United Kingdom-built Advanced Short-Range Air-to-Air Missile (ASRAAM) for the Royal Australian Air Force and the SLAM-ER for Korea. [114] [172]

Joint Strike Fighter (JSF)

The F-35 JSF is a multirole fixed-wing stealth aircraft that provides air superiority, close-air support, and tactical bombing for the U.S. Navy, Marine Corps, and Air Force. It comes in three general variants: the conventional takeoff and landing version for the Air Force, which is scheduled for initial operational capability in 2013; the short takeoff and vertical landing version for the Marine Corps, which is scheduled for initial operational capability in 2012; and the carrier-based takeoff and landing version for the Navy, which is scheduled for initial operational capability in 2014.

NAWCWD supports weapon integration in the new F-35 JSF in much the same way that it does for the F/A-18; however, with the F-35's internal stores, the process is exponentially more complicated. To maintain a small RCS, the F-35 carries its munitions in four internal stations. However, if stealth is not a factor, the F-35 has the ability to carry munitions, pods, and fuel tanks externally on the centerline and wings, thereby increasing the number of stations from 4 to 11. NAWCWD is responsible for integrating several weapon systems on all variants of the F-35, including the Sidewinder, JSOW, LGB, DMLGB, AARGM, JAGM, and the Joint Standoff Missile. [172] [204]

Joint Service Efforts

Apart from integrating weapons on Navy platforms, NAWCWD also supports integration of weapons and systems on Marine Corps and Air Force aircraft, specifically the AV-8B and F-22. For the F-22, NAWCWD took the lead in integrating the Sidewinder missile to help ensure that the F-22 will have the air dominance for which that aircraft was designed. NAWCWD helped bring a number of weapons and weapon systems to the AV-8B, including the Intrepid Tiger and LITENING pods, JDAM, LJDAM, DMLGB, AMRAAM, and many others. NAWCWD is also supporting an effort to provide the AV-8B the capability to carry multiple precision-guided missiles with the BRU-70/A Digital Improved Triple Ejection Rack. NAWCWD achieves all this through the AV-8B AWL, which, like the F/A-18 AWL, was also given a Level 4 rating by the Software Engineering Institute. [172] [204]

Weapon Systems

TARGETING SYSTEMS

Active Electronically Scanned Array (AESA)

AESA is a fire-control radar that increases the F/A-18's air-to-air target detection and tracking range and provides higher resolution of air-to-ground mapping at longer ranges. Performance and capabilities of past airborne radars were 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. [54] [172]

The first flight of the integrated APG-79 AESA radar was in a U.S. Navy F/A-18 Super Hornet at China Lake in 2003. OPEVAL began in 2005, heavily supported by VX-31. As a result of that work, the AESA radar entered full-rate production in 2007. In 2008, the radar deployed for the first time with VFA-22. [54] [172]

Advanced Targeting Forward-Looking Infrared (ATFLIR) System

China Lake's work with IR devices dates back to its beginning, when, in the 1940s, Dr. William B. McLean built the IR-homing Sidewinder missile. Since then, China Lake has been a Center of Excellence for IR research and development. Over the years, China Lake put IR technology to a variety of uses, including developing a myriad of FLIR devices—from cockpit displays to night-vision goggles. One of the latest examples of FLIR technology is the ATFLIR system. [141]

The ATFLIR is an airborne targeting and navigation system designed for use on the F/A-18C/D Hornet and F/A-18E/F Super Hornet. It combines and replaces three previously separate systems: the AN/AAS-38A/B targeting FLIR, the AN/AAR-50 navigation FLIR, and the AN/ASQ-173 laser designator tracker/strike camera. ATFLIR allows the Warfighter to accurately deliver air-to-ground weapons from beyond the range of antiaircraft artillery and many SAM systems. It is one element that makes the Navy's F/A-18 the premier strike platform. [204]

In 2001, ATFLIR entered low-rate initial production. In 2002, before China Lake had performed OPEVALs, ATFLIR was awarded early operational capability to provide the Warfighter a critical advantage in the War on Terror. Initial operational capability was finally granted a year later after successful completion of OPEVALs. Block II completed integration testing and passed the operational test readiness review milestone, and VX-9 is now performing follow-on T&E at China Lake. [172] [204]

Digital Precision Strike Suite (DPSS)

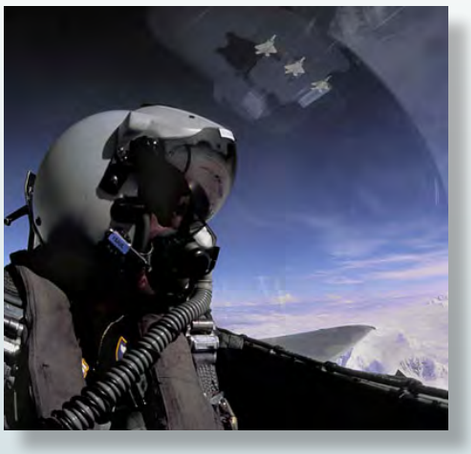
The DPSS is a self-contained laptop system that increases the success of first-pass attacks with smart weapons, thus providing a brand new capability for the Fleet. In less than 1 minute, the computer correlates real-time target images from various sensors with existing geographical database imagery and assigns a latitude, longitude, and elevation to any part of the target. The operator can then transmit these targeting data to the aircraft and weapon. [55]

The DPSS team is located at China Lake and has developed a suite of software applications for targeting. The PSS-SOF application, developed by the DPSS team, is currently used extensively in Afghanistan and Iraq in support of ground combat engagements. PSS-SOF allows the Special Operations Forces joint terminal attack controller, joint fire observers, and other trained users to provide highly accurate eyes-on precision target coordinates to any other target planning system or available weapon delivery system. Increased precision allows greater speed in target destruction, fewer and smaller weapons, fewer civilian and military casualties, less collateral damage, and the use of fewer delivery platforms, thereby resulting in lowered costs. [172]

In 2006, the DPSS scene matching software evolved with precision fire image and was urgently requested by the U.S. Marine Corps and the U.S. Army. The high effectiveness and field portability of this system have added thousands of Special Operations Forces and Army users to the targeting community. Multiple joint exercises involving the DPSS precision fire images application were conducted in 2007. In 2008, a pocket-sized forward entry device was introduced in a collaborative effort among the Army, USJFCOM, and China Lake. In addition, a prototype DPSS system was installed on USS *John C. Stennis* that can rapidly anchor a tactical image to the DPSS database to produce a highly accurate coordinate that can be used to target precision-guided weapons. USS *John C. Stennis* requested installation of this prototype for use during operational deployment in support of the War on Terror. [71]

The DPSS tools have now moved beyond the tactical aviation community as a force multiplier to the Army artillery community. For example, PSS-SOF is being taught in theater by U.S. Central Command and the Naval Strike and Air Warfare Center (NSAWC) and was formally integrated into schoolhouses from all services, including the Army Artillery Schoolhouse at Fort Sill, Oklahoma. [170] [172] [219]

Joint Helmet-Mounted Cueing System (JHMCS)



The JHMCS allows pilots to aim sensors and air-to-air and air-to-ground weapons and view flight parameters without using the aircraft's instruments or heads-up display (HUD). This system gives pilots the advantage of first-shot high off-boresight weapon engagement in the high-*g* within-visual-range air-to-air environment by allowing pilots to look, lock on, and fire without having to maneuver their aircraft into position. Without this system, pilots could not fully utilize the agility and high angle-off capability of missiles like the AIM-9X. In air-to-ground engagements, JHMCS enhances lethality and survivability by reducing cockpit head-down and target-acquisition times. Initially, JHMCS was used by single-seat aircraft or by only the pilot in dual-seat aircraft, thereby limiting JHMCS's potential. However, in 2008, China Lake completed developmental testing of the aft-seat installation of JHMCS, which greatly improves aircrew situational awareness and enables target acquisition from either cockpit in both air-to-air and air-to-ground engagements, thus significantly improving F/A-18 lethality and survivability. China Lake also completed developmental testing of Mini-Quadeye, a two-tube version of Quadeye, the night-vision element in JHMCS. [172] [204]

LITENING Pod

Since 1970, when China Lake released the laser spot tracker, NAWCWD has made continual progress in the development of laser TDDs. One of the latest systems in that effort is the LITENING pod, a laser target designator pod offering precision strike in day, night, and adverse weather conditions for fighter and tactical strike aircraft. To achieve this goal, LITENING has a high-resolution FLIR sensor and a charged coupled device camera for target imaging in both the visible and invisible spectra. It has a wide field-of-view search capability and a narrow field-of-view targeting capability. An inertial navigation sensor has line-of-sight and automatic boresighting capability. Lastly, LITENING has a laser designator, laser tracker, and laser marker for precise delivery of laser-guided munitions. [141] [204]

As a result of an ongoing effort at China Lake, the LITENING pod can now be utilized by several aircraft platforms. In 2003, the F/A-18 AWL demonstrated the ability to retrofit F/A-18Ds with the pod, and, in 2008, VX-9 completed operational assessment of the integration software for the EA-6B Improved Capability II (ICAP II). [172]

Tactical Dissemination Module (TDM)

The TDM is a revolutionary new portable computer/radio system that creates customized real-time targeting strike packages for specific aircraft. In conflict, the rules of engagement require positive target identification before weapon release, and TDM helps the Warfighter identify the appropriate target. If Special Operations Forces personnel, for example, identify a time-critical target, they can digitally photograph the target, determine the approximate GPS coordinates,

and then transmit the data back to Central Command, which decides which weapon is currently available (target–weapon pairing) to make the call for fire. When the TDM receives the call for fire over a secure network, the target package generator automatically fills in the fields on a computerized worksheet and formats the information into a standard nine-line message specific to the launch aircraft. Reconnaissance images, as well as preexisting satellite imagery, are then resized 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 (FDE) portable computer/radio field equipment, which then transmits directly into the cockpit of the strike aircraft by one of numerous RF data link methods.

China Lake invented and developed the TDM in 1993 as part of the RPTS project. The Navy's first TDM system was demonstrated in 1994 and was installed on six U.S. Navy ships. In late 2002, the TDM was deployed to the Persian Gulf during Operation Southern Watch. During Operation Iraqi Freedom, as coalition forces captured Baghdad International Airport, the FDE and TDM were immediately relocated there for the duration of the conflict. The TDM supplied more than 900 target packages to coalition bombers during its 8-year deployment (2002-2010) in Iraq. During that time, more than 200 engineers and technicians from China Lake provided the training, sustainment, and technical reach-back for every detachment. Using satellite and relay aircraft, designers are extending TDM's range from the current 180-mile limitation to virtually anywhere in the world. [49] [54] [60] [170]

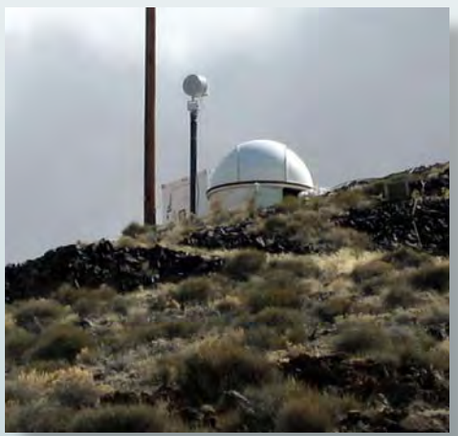
Sensor Systems

Automatic Radar Periscope Detection and Discrimination (ARPDD) System

Existing maritime radars can detect periscopes in open oceans without much difficulty, but, in littoral waters, the effort becomes manually intensive because the system generates numerous false positives that operators must constantly sort through to find target hits. The ARPDD system is a radar upgrade designed to increase the capability of existing maritime radars to automatically detect exposed periscopes in cluttered littoral environments, while maintaining extremely low false alarm rates. The increased capability is provided by a faster antenna rotation rate that allows for increased resolution. In addition, quad processors are used to increase the radar's processing power to accommodate the complex algorithms developed by NAWCWD for the ARPDD system. [172] [208]

A contractor test flight of the ARPDD system being developed for the Navy's MH-60R was conducted in early 2010, and the T&E phase continues on the system, with a tentative 2013 installation date. The ARPDD could eventually be modified and installed on other aircraft, including UAVs, with only minor adjustments to account for differences in flight profile. [172] [208]

Distributed Ground-Based Threat Detection System (DGTDS)



MANPADS underscore the asymmetric nature of modern warfare—one person toting a $25,000 IR-guided missile has the ability to destroy a military aircraft. To counter this threat, NAWCWD developed the DGTDS, an "automated missile warning system designed to provide reliable, timely, and accurate missile location information of shoulder-launched SAMs within the volume under surveillance by a network of sensors." In essence, sensor nodes are placed throughout the area under surveillance and monitor the area between the nodes for threat missile activity. The DGTDS sensors look for the unique signatures of SAMs, while eliminating background interference from other non-threats in the area. When a threat is detected, a signal is sent to a central processing unit to deploy countermeasures. [210]

In 2006, NAWCWD began developmental testing on two-node and four-node systems and fired combinations of MANPADS and rockets to determine launch-detection performance. The system's capabilities were successfully demonstrated in a series of live fire demonstrations for visiting officials, including the Office of the Under Secretary of Defense and the Department of Homeland Security. The DGTDS team received a Commander's Award for their outstanding efforts.

Patriot Radar Rangefinder

The Patriot Radar Rangefinder system is a submarine-mast-mounted miniature contact avoidance and situational awareness radar system. This radar provides, for the first time, precise situational awareness to submerged platforms. NAWCWD, in partnership with the Naval Undersea Warfare Center, developed the radar to fill a capability gap made apparent by the collision of a Los Angeles class submarine with a Japanese research ship off the island of Oahu.

The system was developed and demonstrated in 13 months, and the radar performed as designed, receiving rave reviews from crews familiar with its capabilities. Since then, the Patriot system has been installed on more than 30 U.S. submarines. For their work, the NAWCWD-led Patriot team was nominated for the prestigious David Packard Excellence in Acquisition Award. In 2008, a HUD was added to the Patriot Phase A system to improve observation and search procedures. In 2009, laboratory, land, and sea testing was completed on the Phase B system. The success of these tests led to low-rate initial production by China Lake. [177]

Precision Strike Navigator (PSN)

China Lake initiated the PSN Program to develop advanced inertial guidance components for use in next-generation precision-guided bombs, with particular attention paid to making the fiber-optic gyro more accurate, less costly, and mass producible. The goal of the PSN Program was to create a system that could maintain GPS accuracy in the presence of near-target GPS jamming. Tests were performed at two independent facilities, and the program's performance goals were achieved. The components were also produced by using mass production methods in accordance with program goals. The effort resulted in the only known mass-producible high-performance gyro technology. In 2004, NAWCWD began to transition this technology to industry to produce inertial measurement units for JSOW and JDAM. [172]

Shared Reconnaissance Pod (SHARP)

SHARP is an airborne reconnaissance pod for the F/A-18E/F Super Hornet. The pod provides the Warfighter with the advantage of day or night reconnaissance, nearly real-time data link capability, and nearly instantaneous image processing. The F/A-18 AWL led the software development and integration effort. SHARP achieved early operational capability in support of Operation Iraqi Freedom in 2003 and initial operational capability a year later. The operational assessment was performed at China Lake by VX-9. In 2009, China Lake took the initiative to fix a SHARP cable drive assembly in house. The fix, initially scheduled to take 4 or 5 days, was completed in 2 days and saved the government $145,000. Because of this effort, the cable drive assembly is no longer a "for order only" part, and future repairs will continue to save $145,000 per unit. [55] [172] [204]

To provide an all-weather capability to SHARP, a synthetic aperture radar (SAR) was added. The addition of SAR to SHARP also increased its standoff capability. The NAWCWD F/A-18 IPT was vital to the integration process, and VX-30 performed the necessary testing. [54]

Communication Systems

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. In 2002, a MIDS-equipped F/A-18 from China Lake participated in the Joint Combined Interoperability Evaluation Team exercise that demonstrated the interoperability of MIDS with joint and international platforms. In 2004, Point Mugu led a successful effort to bring the MIDS to the EA-6B platform.

MIDS is currently undergoing transition to the Joint Tactical Radio System (JTRS). The goal of JTRS is to produce a family of interoperable modular software-defined radios that operate as nodes in a network to ensure secure wireless communication and networking services for fixed and mobile forces. In support of this effort, China Lake is conducting test flights of the MIDS JTRS on the F/A-18F. [83] [172] [177] [204]

Rapid Attack Information Dissemination and Execution Relay (RAIDER)

RAIDER is a communication system that significantly improves the dynamic targeting timeline by providing machine-to-machine digital communications for the major data link systems currently fielded. RAIDER operators are able to receive an air support request, build the re-tasking message, and transmit it over the appropriate data link directly to the attacking aircraft or controlling platform.

During the Joint Expeditionary Force Exercise 2006 (JEFX06), a RAIDER concept car demonstrated initial capabilities and new future enabling technologies, such as tactical targeting networking, common data link, and securable tactical cellular telephones. RAIDER has formally transitioned to the Objective Gateway Program at the Electronic Systems Center, Hanscom AFB. In 2007, three RAIDER systems were deployed in Iraq and Afghanistan, and NAWCWD civilian engineers continue to support them in theater.

The RAIDER team also participated in a USJFCOM-sponsored exercise known as "Bold Quest." Bold Quest was a blue force tracking event in which a RAIDER unit was used in a coalition environment to disseminate both blue force position and strike information. The RAIDER Program has been working with the Objective Gateway Program to solidify acquisition plans for an initial operational capability of the Ground Mobile Gateway. NAWCWD is currently working with U.S. Air Forces in Europe on the delivery and support. [172] [180]

Weapon Data Link (WDL)

The WDL is a communication system to provide a low-cost data link for transferring terminal-phase precision target position of moving land targets. The WDL utilizes existing communication bands, and its technology is appropriate to legacy weapon systems. The data link is also compatible with power, weight, and space limitations. [172] [219]

In 2005, the WDL was successfully demonstrated at China Lake by communicating with a JDAM to engage a moving radio-controlled truck. The target's position was continuously tracked by an F/A-18's onboard sensor, and updates were provided by the aircraft's communication system to the JDAM by using the WDL. The two-way link demonstrated WDL's ability to transmit

real-time weapon status back to the host aircraft during the JDAM's free fall. T&E of the WDL are ongoing. [172] [203] [219]

Aircrew Safety

National Parachute Test Range/Naval Test Parachute Team

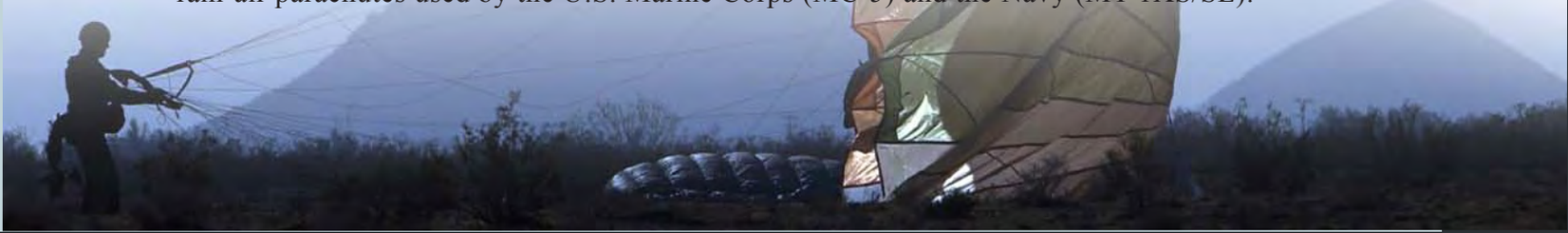
Parachute work has been a central component of aircrew safety at NAWCWD since 1979, when the National Parachute Test Range, along with the Naval Test Parachute Team, was relocated to China Lake. The team tested several novel systems, including the first ram-air parachute and NASA's Space Shuttle crew escape system, and the range was used by many federal agencies, including airborne firefighters from the Forestry Service. Allied countries also traveled to China Lake to test on the range. The British military, for example, tested its High-Altitude Life Support System on it. Although the range and team were officially disbanded in 2005, the Human Systems Department at NAWCWD and qualified parachutists throughout the Fleet continue to improve upon legacy systems and design new systems to guarantee aircrew safety for years to come. [172] [177]

Parachute Qualification

NAWCWD performed the testing to qualify the thin-pack parachute for the P-3 and E-2C aircraft. The new system is, essentially, a vacuum-sealed parachute. Hermetically sealing the pack provides a number of significant advantages: first, the system is very lightweight, roughly half the weight of the Vietnam conflict-era NB-8 system used in the P-3; second, at a 5.5-year repack cycle, the system has a much longer service life; third, the compact size eases egress from aircraft in emergency situations. The types of tests conducted include air drops involving mannequins and aircrew, structural integrity tests at the China Lake Shock Tower Facility, and environmental testing in various temperatures and conditions. The thin-pack system for the P-3 aircraft (A/P22P-21) achieved initial operational capability in 2001, and the system for the E-2C aircraft (A/P22P-20) was released later in the decade. [177]

China Lake also performed qualification testing on the IGQ Type 6000 parachute for use on the new JSF Mk-16E ejection seat. The new system has some distinct differences from pervious systems—like a larger canopy, a central release point, and a harness that is actually incorporated into the ejection seat—thus making testing that much more critical. [172]

The thin-pack parachute and the IGQ Type 6000 are recent examples of parachute testing, but this testing has been done at China Lake for years. For example, in the 1980s and 1990s, China Lake qualified the GQ Type 2000 and 5000 utilized in the Navy aircrew common ejection seat and the ram-air parachutes used by the U.S. Marine Corps (MC-5) and the Navy (MT-1XS/SL). [211]



Ejection Seat Propulsion

In 1957, China Lake was tasked with developing a rocket motor that could successfully eject a pilot from an aircraft during takeoff and landing, at high speeds at low altitudes, and under other less-hazardous conditions. To complicate matters further, the motor had to work in temperatures ranging from -65°F to 165°F and be compatible with those on various Navy aircraft. China Lake met those requirements with the Rocket-Assisted Personnel Ejection Category I (RAPEC I), which was released for production in 1960. RAPEC I was a two-phase booster and sustaining rocket that could successfully eject a 365-pound man–seat mass from an aircraft. Building upon the success of RAPEC I, China Lake developed the RAPEC III, a system very similar to the RAPEC I but with a modified booster assembly to better control the total *g* and the onset rate. [212]

As China Lake made significant advances in weapon propulsion technology, it was able to apply that knowledge to ejection systems. For example, by using thrust vector control technology, China Lake hoped to increase seat stability during launch. Initially, this technology was aimed at providing increased stability to the pitch plane, but studies on multiple-axis thrust vector control techniques were also conducted. The Vertical-Seeking Ejection Seat program took this technology one step further by demonstrating the ability to launch an ejection seat in a nearly inverted position, with the seat then uprighting itself and continuing to fly vertically. A follow-on project, the Microwave Attitude Reference System, provided the seat with local vertical reference, as well as terrain and obstacle avoidance. In the final test of this system, the cockpit was suspended 100 feet above ground level at 135 degrees of roll angle. From this position, the ejection seat dropped less than 30 feet before reorienting itself to a vertical trajectory. The test dummy separated from the seat at 213 feet above the ground and reached a maximum altitude of 237 feet above the ground before the parachute deployed. Although the vertical-seeking escape system, in conjunction with the Microwave Attitude Reference System, provides the potential to greatly reduce aircrew fatalities and injuries, the ejection seat has yet to be released for Fleet use. [151]

Testing

China Lake has several facilities that accommodate testing parachutes, ejection seats, escape systems, and other aircrew safety devices, one of which is SNORT. The SNORT facility contains two separate tracks, one that is 4 miles long and one that is 3,000 feet long, each equipped with a variety of cameras and sensors to capture pertinent test data, such as velocity, range, and azimuth. The facility enables speeds up to Mach 3, thereby allowing NAWCWD personnel to

test aircrew safety systems at speeds similar to those in which the system will be deployed on the aircraft. The G-4 track is particularly ideal for high-speed parachute testing because it terminates at the edge of a 500-foot-deep basin, thus providing more time to deploy and monitor the system. [211] [213]

The HIVAS and drop towers are also used to ensure that aircrew safety systems perform as designed when needed. In the HIVAS, parachutes are tested under high dynamic pressure conditions, similar to in-flight airflow conditions, and drop towers are used to evaluate the structural integrity of parachute systems (i.e., the straps and harnesses).

Fuze Development

Fuzes are critical to a guided missile's success because they cause the weapon to detonate at the point where the explosion will do the most damage. Developing and improving fuze technology were the objectives of one of the first projects assigned to China Lake in the 1940s. When World War II ended, 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 had an integral part in the development of all three.

Since World War II, Warfighter weapons have evolved from traditional general purpose bombs to PGMs, such as LGBs. With these systems, "target kill with one weapon" is expected. To achieve this goal, NAWCWD is increasing the reliability of current bomb fuzes by incorporating techniques employed in missile fuzes. NAWCWD is also streamlining many switches, cables, connectors, lanyards, and initiators to improve the technology.

Advances in fuze technology at China Lake provide the Navy with world-class design capabilities and have included TDDs, contact sensors, electromechanical SADs, and fuze antennas, with hundreds of designs and components in Fleet use. To improve the technology, new fuze systems under development will interface and communicate with the aircraft, thereby eliminating the need for the external fuze components and the associated electrical and mechanical interconnects. These new systems will also increase the weapons' overall reliability and safety; however, this technology is several years away.

China Lake also developed the universal rocket motor AFD to prevent accidents, such as the 1967 disaster aboard USS *Forrestal*. This single device replaced a vast proliferation of rocket motor AFDs that were in the Fleet until the 1970s and offered significant improvements in safety and reliability.

NAWCWD has been involved in countless fuze development projects during its history, but only a few are mentioned in the sections that follow.

Fuze Components and Technology

NAWCWD has developed several fuze components and advanced numerous technologies to improve fuze capabilities. For example, in 1953, China Lake developed the SAD, which is a fuze component that isolates the detonator from the warhead booster charge until the launched weapon achieves a safe distance. SADs ensure safety in missile handling, shipping, storing, and launching. There are nearly

three quarters of a million SADs in the Fleet today. China Lake also developed a universal AFD to remotely safe and arm rocket motor ignition devices.

In the mid-1960s, China Lake developed edge detection for use in most Navy antiair missiles. Edge detection increases the probability of detonating the warhead while the target is within its lethal range, rather than using a simple timed detonation, which makes the warhead explode at a specific time, regardless of the target. In addition, China Lake developed the fore-and-aft adaptive logic used in long-range missiles. As a result of this technology, the warhead detonates at the optimum time.

NAWCWD also applied pseudorandom-noise modulation to TDD designs to take advantage of spread spectrum techniques, in which the transmitted signal is spread over a wide frequency band, thereby providing a lower-density signal than conventional signals. For fuzing applications, this technique makes the signal difficult to detect, while providing a high-resolution target-detection capability.

Electrical Timer Fuze

NAWCWD developed the FMU-143E/B series fuze, which incorporates only a simple electrical timer triggered by a mechanical escapement. This fuze has been the legacy unit for hard-target bomb configurations because it does not use complex logic. Variants of this fuze exist for the Navy and the Air Force.

Active Optical Fuze

China Lake developed the first active optical fuzes using solid-state lasers. TDDs use an active source, such as a laser, to detect the target. The active optical TDD provides high-range resolution information and narrow-beam control, thereby improving the ability to place the warhead fragments on the target. Active optical fuzes are used in TDDs for antiair and anti-surface missiles. For example, the DSU-10 fuze was developed by NAWCWD in 90 days during 1968 to meet a Vietnam conflict requirement and was used on the Standard ARM. The DSU-15 laser proximity fuze was developed for the Sidewinder missile, and the DSU-19 fuze was developed for the HARM.

Electronic Bomb Fuze

In 2005, NAWCWD began working on a spiral development that extended operational time, expanded arm/delay time options, improved weapon interface, and significantly increased reliability. The FMU-139C/B electronic bomb fuze, the first phase of this progression, increased the reliability of bomb fuzes from 75 to 98%. This fuze is an electromechanical impact/impact-delay fuzing system incorporating an in-flight cockpit setting capability with multiple arming and multiple function delay sections. The FMU-139C/B fuze is being tested for use in several weapons, including JDAM. Several successful live fire bomb tests were conducted in 2009, and fuze manufacturing is in progress, with deliveries already being received for Fleet use.

The FMU-164 is the next-generation electronic bomb fuze being developed by NAWCWD. This fuze will combine the electronic capabilities of the FMU-139C/B fuze with the hard-target penetration capabilities of the FMU-143 fuze. This fuze is expected to be operational for Fleet use in 2016.

Electronic Warfare (EW)

Electronic Warfare (EW)

In addition to the more-conventional forms of airborne warfare (i.e., bombs and missiles), NAWCWD also possesses expertise in EW (i.e., radar jammers and countermeasure devices). NAWCWD has the personnel, the facilities, and experience to provide the Warfighter with every possible advantage in prosecuting EW missions. The EA-6B Systems Integration Facility at Point Mugu, for example, is the only airborne electronic attack facility of its kind, and VX-9 conducts operational T&E of EW systems and software for Navy and Marine platforms.

EA-6B Prowler

The EA-6B Prowler, an EW platform based on the A-6 Intruder strike aircraft, provides soft- and hard-kill SEAD and signals intelligence for the U.S. Navy and Marine Corps. To ensure its relevancy over the course of its operational life, the EA-6B has undergone consistent upgrades, resulting in nine variants, from the Standard version that entered the Fleet in 1970 to the ICAP III version released in 2005. NAWCWD supports this work with development and testing at both China Lake and Point Mugu. In fact, Point Mugu is responsible for hardware and software integration for the EA-6B. As such, that organization's contributions are too many to list in full. However, some examples of that ongoing effort will help to illustrate the advantage provided to the Warfighter by Point Mugu through the EA-6B platform. [204]

Point Mugu developed the software and displays that enable the MIDS to work with the EA-6B. The system provides the EA-6B aircrew with increased situational awareness and data management capabilities, improves traffic separation, reduces task load, and allows for GPS non-precision approaches. The EA-6B was the first tactical Navy aircraft to have these capabilities. The AN/ALQ-218(V) Tactical Jamming Receiver (TJR) system also provides increased capabilities to the EA-6B, and Point Mugu was once again an essential component in bringing that capability to the Fleet. [92] [172] [204]

Point Mugu integrated, tested, and validated the AN/ALQ-218(V), the designated receiver system for the EA-6B ICAP III used in conjunction with the AN/ALQ-99F(V) Tactical Jamming System (TJS). This receiver allows the EA-6B to carry out selective reactive narrowband and reactive full-band jamming; cue the HARM in its most effective range; and perform jamming, surveillance, and missile launches simultaneously. For the ALQ-218 to perform as designed, complex software must be developed to control it and the systems with which it interacts. These software programs are called Operational Flight Programs (OFPs), and NAWCWD has been a leader in EA-6B OFPs for decades. [204]

As the Electronic Warfare Software Support Activity (EWSSA), Point Mugu supports all EW software, including OFPs, for the EA-6B. NAWCWD releases OFPs to the Fleet yearly for various reasons (e.g., to integrate new hardware onto the platform, to increase the capability of existing hardware, or to allow the platform to engage new threats) but always with the singular goal of providing the Warfighter every advantage possible. VX-9 lends its support to this process by flight testing the software to validate its performance; catch any defects; and, if defects are found, recheck the system once the defects are remedied. The Airborne Electronic Attack IPT at Point Mugu has so much expertise and experience that the team was chosen to provide development, test, and integration support for the EA-18G EW platform. To help with this tasking, the EA-18G Systems Integration Laboratory was built at Point Mugu. [92] [172]

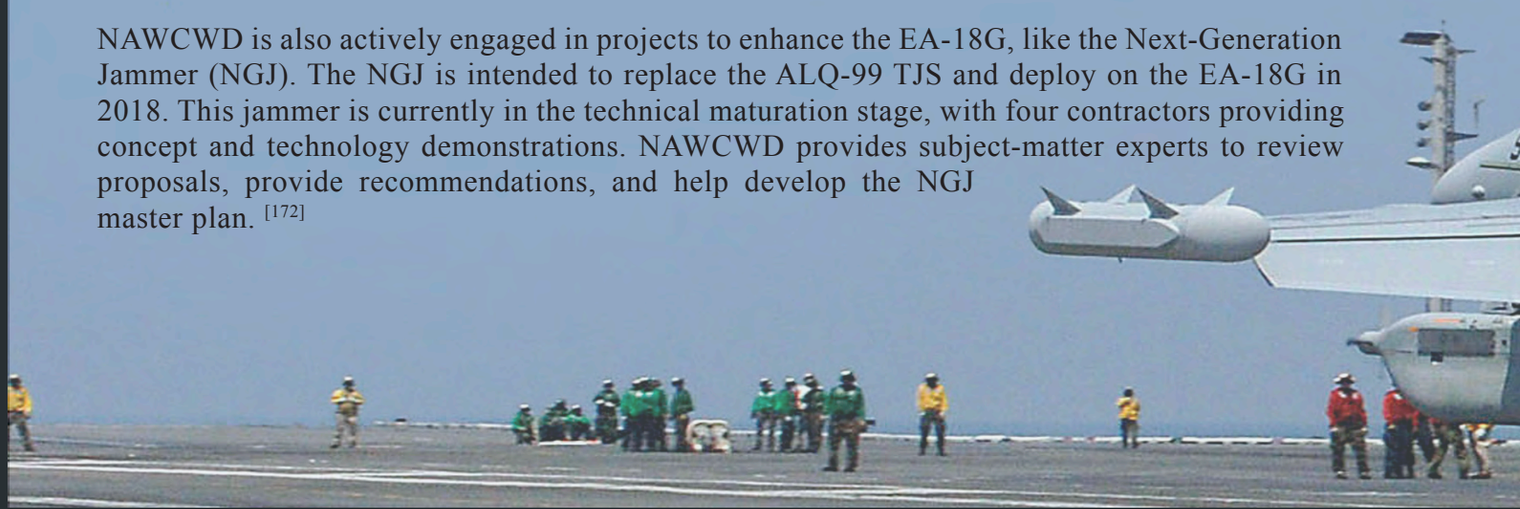
EA-18G Growler

The EA-18G Growler is the Navy's new EW platform that will eventually replace the EA-6B as the cornerstone of the Navy's airborne electronic attack mission. The EA-18G aircraft is based on the F/A-18F Super Hornet platform and provides electronic attack and SEAD capabilities similar to those of the EA-6B, but with several major advantages over the legacy aircraft. First, the EA-18G has afterburners, thus making it faster and more maneuverable than the EA-6B. The EA-18G also has greatly enhanced jamming, communication, and radar equipment. For example, the EA-18G has the ability to communicate with other aircraft and ships, while simultaneously performing its jamming mission—thanks to the Interference Cancellation System (INCANS). Because the EA-6B could not perform those functions concurrently, it had to risk being off-line for up to hours at a stretch. Another important advantage the EA-18G has over the EA-6B is the increased number of pods carried—nine to the EA-6B's five. This increase allows more flexibility in EA-18G mission planning by allowing the platform to carry a variety of jammers, radars, fuel pods, and air-to-surface and air-to-air weapons, without having to sacrifice one for another. The ability of the EA-18G to carry air-to-air weapons is, in itself, an increased capability from the EA-6B. The EA-18G can carry two AIM-120 AMRAAMs for self-protection. The EA-18G was released to the Fleet in late 2009, but, before that could happen, years of development and testing were conducted, in which NAWCWD took a large role. The following paragraphs describe some highlights of that effort. [170] [172] [204] [214]

In much the same way that it did for the EA-6B, NAWCWD supported integration efforts on the EA-18G. In one effort, Point Mugu performed integration work on the INCANS and ALQ-99 TJS to give the EA-18G that critical ability of simultaneous jamming and communication mentioned earlier. Other integration efforts include the APG-79 AESA radar, the ALQ-227 Communication Countermeasures System, the ALQ-218 TJR, the HARM, and the AMRAAM. The EWSSA at Point Mugu also performs software work on the EA-18G, developing, updating, and releasing OFPs, EW software suites, threat files, rapid reaction files, electronic intelligence files, and other software as needed. [204]

NAWCWD T&E squadrons also supported the EA-18G, testing both software and hardware. Tests included developmental and operational testing of the entire EA-18G system and its subsystems, including the first live fires of the AMRAAM and HARM over the China Land ranges. [204]

NAWCWD is also actively engaged in projects to enhance the EA-18G, like the Next-Generation Jammer (NGJ). The NGJ is intended to replace the ALQ-99 TJS and deploy on the EA-18G in 2018. This jammer is currently in the technical maturation stage, with four contractors providing concept and technology demonstrations. NAWCWD provides subject-matter experts to review proposals, provide recommendations, and help develop the NGJ master plan. [172]



Acknowledging Success

NAWCWD has received a variety of awards in recognition for its contribution to the field of EW. The following is a short list, in no particular order, of some of those honors. [215]

- The EA-18G Flight Test Team, which consisted of VX-9, VX-31, VX-30, and the AWL, received the 2007 Society of Flight Test Engineers James S. McDonnell Award for Outstanding Team Achievement in the Field of Flight Test Engineering.
- Point Mugu received a Congressional Record Acknowledgment from the Honorable Elton Gallegly in tribute to the Electronic Warfare Center of Excellence and its past and current contributions to our national defense.
- The EA-6B ICAP III and the EA-18G Tactical Aircraft Programs were awarded the 2006 David Packard Excellence in Acquisition Award as a result of their teamwork synergies.
- The Jet-Assisted Takeoff (JATO) Team at Point Mugu earned the Marine Corps Semper Fidelis Award in 2006 for fielding an essential new jamming capability for the Marine Corps in support of the War on Terror.
- The Association of Old Crows awarded the EA-18G IPT its IPT of the Year Award in 2008 for furthering the aims of the association in support of U.S. or allied EW.
- The EA-18G IPT received National NAVAIR Commander's Awards in 2008 for achievements in RDT&E and science and technology.
- The Electronic Warfare Database Support Team received a National NAVAIR Commander's Award in 2009 for their quality of service.

“I can tell you that systems developed and tested at WD [the Weapons Division] played a critical role in our success in Fallujah, including DPSS, TDM, and the F/A-18 aircraft integration of the GBU-38, the 500-pound JDAM. I personally witnessed a GBU-38 surgical strike take out a building being used by insurgents in a crowded neighborhood, while leaving the buildings next door unharmed. The work done at WD is making a difference in the War on Terrorism.”

—Captain Dan Lee
Military Director, Weapons and Energetics Department

Unmanned Systems (UxS)

Unmanned Systems (UxS)

Mission. NAWCWD is one of the Navy's foremost activities that field UxS. Several teams, including the Unmanned Systems Activity (USA), are involved with this UxS effort. The USA is responsible for UxS in all domains—air, ground, surface, and subsurface—and provides all the components needed to launch, control, and recover these systems. In addition, NAWCWD is a technical lead for UxS sensors, weapons integration, cost and effectiveness analyses, and T&E.

In fiscal year 2011, UxS efforts outpaced those for manned systems in terms of total flight hours accumulated and revenue generated for the China Lake Land Ranges. UxS work is a strategic thrust area for NAWCWD, and UxS work continues to grow.

NAWCWD—Early Pioneer of UxS Technology

UxS are no longer in the realm of science fiction and have become a real and effective weapon in reconnaissance and close-air support. NAWCWD has a long history of proven capabilities in this field and has been a significant force in bringing many new technologies to today's warfighters.

NAWCWD's aerial target drones of the 1960s—typically refurbished and reconfigured combat aircraft, such as the QF-4 Phantom II—are precursors to today's unmanned aircraft. The supersonic QF-4, a reusable full-scale target drone modified from the F-4 Phantom, provides a realistic full-scale target for air-to-air weapon system evaluation, development, and testing. The drone can be flown by remote control or with a safety pilot to monitor its performance. The QF-4 is equipped to carry electronic and IR countermeasure systems to fully evaluate fighters, as well as weapons flown and fired against it. Full-scale drone aircraft can be operated entirely by computer or be controlled manually during takeoff and landing by using a mobile control station located at the drone runway.

In 1985, NAWCWD supported UAV development, test, and evaluation programs with its efforts in the BQM-74C and the Pioneer remotely piloted vehicle programs. Point Mugu flight tested the Pioneer UAV, while China Lake conducted net testing—recovery of the aircraft after launch. Pioneer later gained fame during Operation Desert Shield and Operation Desert Storm after flying hundreds of surveillance sorties. One of the most iconic images from Operation Desert Storm shows a group of Iraqi soldiers surrendering to a Pioneer aircraft—the first time enemy soldiers had ever surrendered to a UAV. The enemy was soon captured by U.S. ground troops. The Pioneer program officially ended in 2008, but the success of Pioneer led to the development of an array of more advanced aircraft. Today, the Pioneer systems are being reconstituted as target drones. These are just a few examples of NAWCWD's successful early history in the evolution of UxS.

NAWCWD UxS Firsts

First Flights

- Northrop Grumman Corporation's RQ-8 (Fire Scout) and X-47A (Pegasus)
- FAA-authorized transcontinental flight from Patuxent River to Point Mugu by Northrop Grumman Corporation's Global Hawk
- Navy's ScanEagle

First Launches

- AGM-114P against moving target from Army Sky Warrior; single AGM-114 (Hellfire) off MQ-1 (Predator A); and ripple fire of AGM-114s from MQ-9 (Predator B)
- Air-to-Air Stinger from MQ-1

First Releases

- GBU-39 JDAM from MQ-9 (Reaper)
- GBU-12 (Paveway II) from MQ-1 and MQ-9 (Reaper)
- GPS-guided small smart bomb (SSB) from the Boeing X-45A

Other Noteworthy Firsts

- First to support UAV search and rescue on land and at sea with Predator B
- First full power GPS jamming testing against MQ-9

NAWCWD—Current UxS Role

NAWCWD Combat Support

NAWCWD personnel integrated, tested, and qualified for flight a number of specialized unmanned air system payloads to support combat operations in Operation Enduring Freedom and Operation Iraqi Freedom. The integrations were conducted as rapid acquisition projects—each being completed in less than 18 months. These systems are regularly used to support combat operations. Additional prototypes and integration of new capabilities have been requested.

UAV Success in War on Terror, Osama bin Laden

According to a May 17, 2011 article in the *Washington Post* entitled, "CIA flew stealth drones into Pakistan to monitor bin Laden's house," the United States employed sophisticated new stealth drone aircraft to fly dozens of secret missions to monitor the compound where Osama bin Laden was eventually killed. Drones provided high-resolution video that satellites could not provide. The article explained that drones were also used on the night of the raid, providing useful imagery for President Obama and his national security team. The new drones represent a major advance in the capabilities of remotely

piloted planes, which have been the signature weapon against terrorism since September 11, 2001. As one of the Navy's foremost activities to field UxS capabilities, NAWCWD is proud to be part of a national DoD team developing new tools for today's warfighters.

UxS Full-Spectrum Support

There are few places in the nation where UxS customers can enjoy full-spectrum (cradle-to-grave) UxS RDT&E support. Regardless of the stage of development, from new unproven systems to battle-tested systems pushing the weapons test envelope, NAWCWD can handle any requirements. Whether the customer needs large time and airspace blocks for sensor operator training or multiple weapon launch scenarios, NAWCWD supports many concurrent operations. In addition, NAWCWD controls military restricted airspace, so authorized customers do not need to obtain an FAA certificate of authorization to operate UAVs on the ranges.

Intellectual Capital

With more than 2,000 science and engineering professionals (47% of workforce) and more than 600 science and engineering technicians (15% of workforce), including 100+ PhDs and 600+ employees with master's degrees, NAWCWD has the highly advanced intellectual capital necessary to respond to any urgent DoD or contractor requirement.

Cost Efficiencies/Optimum T&E Weather

Benefitting from more than 350 clear days per year, NAWCWD has optimum meteorological conditions that few UxS testing locations nationwide can match. If there is a technical problem, a customer can reschedule to fly the next day, if necessary. Customers save time and money by testing in one location.

UxS Weaponization

The UxS field has evolved so rapidly that there has been very little standardization. There are a multitude of size designs, ranging from very large platforms (equivalent to airliners) down to vehicles that can fit in the palm of a hand and can fly over land and sea, and some that operate in undersea environments. Therefore, engineers are considering all possibilities across a broad spectrum when developing future weapon options.

Forward-Firing Miniature Munition (F2M2) (Formerly Called Spike)
China Lake is credited with developing the world's smallest guided missile, the F2M2. Weighing about 6 pounds, this fire-and-forget missile is approximately 24 inches in length and is suitable for a variety of unmanned and manned systems; it is accurate and portable—designed to be shoulder- or platform-launch capable.

Miniature Guided Bomb Unit (MGBU)
Engineer teams are researching and developing the MGBU, a miniaturized gravity bomb for line-of-sight applications. The MGBU weighs less than 4 pounds and is designed for accuracy, with minimal collateral effects. It can be utilized by small UAVs such as the small tactical unmanned aerial system (STUAS) and RQ-7 Shadow.

GPS-Guided Miniature Munition (G2M)
Engineers are developing a 40-millimeter-sized precision miniature munition called the G2M for non-line-of-sight applications. It is intended to be compatible with shoulder- or platform-launched applications. G2M is undergoing navigation testing and development of other critical system components and subsystems. Future development options may include integration of sensors and components to expand capability and increase range.

The F2M2, MGBU, and G2M are being developed to provide small UxS and dismounted forces with a standoff precision engagement capability with minimal collateral effects.

UxS Payload Integration—System-of-Systems Standards-Based Approach

UxS platforms require multiple payload capabilities with various size, weight, and power constraints. Since point solutions are often unaffordable and unsustainable, China Lake designed, built, and applied system-of-systems engineering to develop a standards-based stores management approach that is both platform and payload agnostic. The small, lightweight, low-power, interoperable system can be integrated across domain platforms for strike and force protection with many payloads—including nonlethal weapons. In addition, NAWCWD has made significant advances in MEMS, nanotechnology, micro-explosives, and super-capacitor technology that are significantly reducing the size and weight power supply requirements for UxS. Nanoplasmonics and metamaterials accommodate the need for miniaturization of optoelectronic components that are critical to reduce the footprint and weight of future weapon systems. With more than a dozen unmanned combat system firsts in the industry, NAWCWD maintains a strong leadership position in the UxS battlefield of tomorrow.

Shipboard Efforts
- Performed ship integration efforts for Pioneer; maritimized vertical takeoff-and-landing UAV system (MAVUS); Tactical Air-Launched Decoy (TALD) and Improved Tactical Air-Launched Decoy (ITALD)
- Performed shipboard flight certification and operational demonstration with MAVUS
- Performed shipboard operations with Fire Scout unmanned aerial system (UAS)

Naval Integrated Operations
- Integrated Predator UAS flown from San Nicolas Island into Fleet Composite Training Unit Exercise 96-1A for training exercise surveillance, reconnaissance, mini-strike (day and night), and mobile target track support
- Integrated Predator, ScanEagle, and Raven UAVs into Tomahawk operational test launch, an effort that allowed for tactical targeting and battle damage assessment
- Demonstrated successful tactical control system (TCS) level 5 command and control (using Block 0 with Predator, Block 2 with Fire Scout)
- Participated in the unmanned combat air vehicle (UCAV) integration for Predator/Reaper Hellfire, GBU-32, and Fire Scout Hydra 2.75-inch rockets
- Support and host Black Dart counter-UAS flight operations on an annual basis
- Conduct flight test programs for the entire array of UxS

UxS Flown/Tested on NAVAIR Ranges

UxS Land Range Testing

The following have been flown/tested on NAVAIR ranges: AeroLite, Aerosky, Aerosonde, Amber, Dakota, Dragon Eye, Exdrone, Falcon Prowl (United Kingdom), Fire Scout, Global Hawk, Global Observer, Hunter, Joint Unmanned Combat Air System (J-UCAS) X-45A, MAVUS, Medium-Altitude Endurance UAV (MAE UAV) (MQ-1, MQ-9), Micro Air Vehicle, Pegasus, Pioneer, Pointer, Predator, Raven, Reaper, REECE, ScanEagle, Shadow, Sky Owl, Sky Warrior, Swift, Switchblade, TALD, TCS, Tilt Rotor UAV System (TRUS), UAV-Medium Range (UAV-MR), UAV-Short Range, Vertical Takeoff and Landing Tactical UAV, Wasp.

Drone Aircraft and Surface Craft Testing

Testing has been conducted on the following: AQM-37, BQM-34, BQM-74, BQM-126, BQM-145, High-Speed Maneuverable Seaborne Target (HSMST), KD-2R5, MA-31, MST, QF-4, QF-86, QST-35, Vandal.

UxS Sea Range Testing

A wide variety of UxS have been tested on the Sea Range, including ScanEagle flights supporting the Collaborative On-Line Reconnaissance Provider Operationally Responsive Attack Link (CORPORAL) JCTD; the Broad Area Maritime Surveillance–Demonstrator (BAMS-D); RQ-8A ship testing—MQ-8B Fleet Operational Site (2013); Raven Acceptance Test Plan and Fleet Demonstration; AeroVironment fleet of vehicles (Puma, Switchblade, Wasp); and the Predator fleet exercise.

UxS Research and Development (China Lake and Point Mugu)

Active Protect Payload

The objective of the active protect payload effort is to provide the Warfighter with a safer operational environment and extended remote operations for unmanned ground vehicles (UGVs). The active

protect payload consists of warning mechanisms and a malodorant deterrent that are controlled through an operator trigger or an autonomous response, which are both under development at NAWCWD. Multiple sensors, such as an RF identifier or a 360-degree camera, provide situational awareness to determine potential threats.

Command and Control Software

NAWCWD and ONR engineers are improving the interoperability of command and control software. Early UxS command and control software required extensive links. Each link was a tightly engineered point-to-point connection that had to be individually designed, built, tested, and maintained. In 2008, NAWCWD engineers studied service-oriented architectures (groups of services that communicate with each other) to understand how this technology might improve UxS control. In the Tactical Metadata project, engineers analyzed three extensive DoD command and control software architectures and modified one by using a Simple Object Access Protocol consumer-based web service (proven, stable Hypertext Transfer Protocol [HTTP] technology). Final side-by-side comparisons of the three software architectures showed no difference in performance, but the adapted software required far fewer connections. NAWCWD is now collaborating with ONR to improve upon that organization's force discovery service software, which has similar capabilities. Combined research results will save the DoD millions of dollars in total life-cycle costs by reducing manpower, eliminating the need to buy a new control station for every UxS (users will simply buy the command and control service that will control multiple platforms), and reducing the resources required for payload integration—integration with one system instead of many. These new tools are making it easier to get the right information to the right person at the right time so that the correct decision can be made.

CORPORAL and Project Cassandra (2008-2011)

NAWCWD provides invaluable support for CORPORAL, a JCTD effort. CORPORAL was designed to integrate an on-demand electronic attack capability onto a UAS to assist ground troops. Part of that effort was Project Cassandra, which demonstrated the ability to integrate a networked electronic attack capability onto a UAS; it also provided an extension of line-of-sight connectivity to ground forces. Project Cassandra involved utilizing the Iron Nail III electronic attack payload on an Aerostar UAS to demonstrate the advantage that UAVs can provide to the Warfighter.

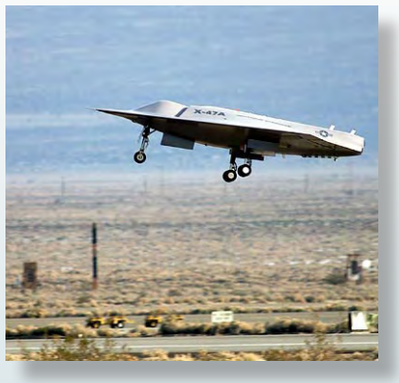
Fire Scout Payload Integration

The objective of the Fire Scout payload integration effort is to integrate a multiple payload capability onto the VTUAV to allow intelligence, surveillance, and reconnaissance (ISR) missions to capitalize on targets of opportunity and shorten the kill chain. The complete payload control suite was integrated into the existing MQ-8B airframe.

Joint Unmanned Combat Air System (J-UCAS)

NAWCWD acted as the Navy's technical lead for the J-UCAS program in software, sensors, weapons integration, cost and effectiveness analyses, and T&E. The J-UCAS was intended to provide autonomous surveillance, SEADs, and strike capability for the Air Force and Navy. NAWCWD supported the program from its earliest stages. The very first flight of an experimental J-UCAS at China Lake was conducted

on February 23, 2003. Weapon drops from Boeing's X-45A UCAV were also conducted on NAWCWD ranges, and Predator/Stinger tests have also been carried out here. NAWCWD was the M&S lead for this effort. The J-UCAS program has helped spawn the Navy–Unmanned Combat Air System (N-UCAS), Unmanned Combat Air System–Demonstration (UCAS-D), and Unmanned Carrier-Launched Airborne Surveillance and Strike (UCLASS) efforts—all of which were supported by NAWCWD.



Microelectromechanical Systems (MEMS)

NAWCWD continues to develop multi-point initiation systems for MEMS devices. Extensive testing with MEMS is being conducted to contribute to the production of micromachines, micro-integrated circuits, and microoptics for UAS applications.

Metamaterials and Nanoplasmonics

The need for miniaturization of optoelectronic components is critical to reducing the footprint and weight of future weapons systems. The latest NAWCWD developments offer the potential to overcome diffraction limits, thus enabling devices to be built in the sub-wavelength scale. Another newly discovered application of these metamaterials is a novel physical effect of the nonlinear properties. Nonlinear metamaterials can shield objects from high-power laser beams. It has been observed that the shielding strength increases with increasing laser power. Investigations are being conducted in areas such as metamaterial antennas for UxS, as well as nanoplasmonics.

Petrus Engagement Technology for UxS

The goal of the Petrus effort is to provide a precision targeting solution to meet current ISR and fleet force protection needs. NAWCWD's role is to develop exploitation algorithms for hyper-spectral imagery and integrate those algorithms onto small UxS and their control stations. This technology applies to ground, air, and surface platforms. Petrus could be deployed on UxS for ISR target classification support, maritime protection, and ground force protection from oncoming vehicles and insurgents.

Radiant Virgo

In the Radiant Virgo effort, NAWCWD researchers developed an application that provides automated geo-registration of tactical full-motion video obtained from UAS electrooptical and IR sensors. With the use of commercial imagery and a digital point positioning database, the system can derive precise and accurate coordinates to aircraft or PGMs to engage targets in nearly real time.

Raven

The Raven is a small 4-pound UAS that is used by the Marine Corps and Navy for ISR support to small tactical units, such as Marine company-sized units. NAWCWD supports RDT&E of special payloads and sensors for targeting and for ISR. The Raven incorporates an electrooptical (IR) sensor and a targeting camera, is hand-launched by a single operator, and has no runway requirement.

Raven Advanced Targeting (RAT) Payload

The goal of the RAT payload effort is to provide operating forces with an organic capability to map (in high detail) areas of interest. NAWCWD developed precision targeting software that was used to achieve imagery resolution that is sufficient to provide category 1 target coordinates. The software is located on the forward observer system.

ScanEagle

ScanEagle is a 40-pound UAS used for ISR missions by Marines and Special Operations Forces on the ground and by Navy ships at sea. ScanEagle has a longer endurance capability and can carry more payload than the Raven. The RDT&E of special payloads and sensors support targeting and ISR efforts that utilize small UAS. Several of the payloads now being integrated at NAWCWD will be sent directly to the theater to support operations. The ScanEagle requires only one or two operators and is capable of auto-takeoff and auto-recovery. Other capabilities include forward control. This UAS incorporates an identification friend or foe transponder, an electrooptical or IR camera, and a Remotely Operated Video Enhanced Receiver (ROVER) downlink. No runway is required for launch and recovery.

Super-Capacitor Technology

Working with private industry, NAWCWD researchers are developing super-capacitors to significantly reduce the size and weight of the power supply units, as well as the portable electronic devices used for the communication, computing, surveillance, and sensing functions, for air weaponry and UAVs. Another goal is to utilize safer and more environmentally friendly materials.

Ultra Endurance Unmanned Aerial Vehicle Heavy Fuel Engine (UE UAV HFE)

A team led by NAWCWD and including Aircraft Division and Army Research Laboratory personnel created the UE UAV HFE, a lightweight, efficient heavy-fuel engine. The engine, when tested at Patuxent River and at contractor facilities, demonstrated the required power, weight, and efficiency. This effort is aligned with DoD's single-fuel initiative to improve safety and simplify logistics and to improve durability and altitude performance.

UAS Mission Training Device

NAWCWD engineers collaborated with Army engineers to develop a standards-based simulation training system that provides UAS operators with a virtual environment for proficiency training, mission rehearsal, and emergency procedures applications. The system uses 100% government off-the-shelf/commercial off-the-shelf software and is used to simulate the control of STUAS or any STANAG-4586 command and control aerial vehicle system. Currently, the system provides training for the Army's Shadow, Hunter, and Extended-Range Multipurpose Programs.

Unmanned Ground Vehicles (UGVs)

NAWCWD personnel are conducting R&D of new capabilities of ground vehicles. The UGVs' functions include explosive ordnance disposal (EOD)/bomb disposal, route clearance, and reconnaissance. A demonstration grew out of a CRADA between NAWCWD and the iRobot Corporation to work with the Marine Experimentation Center to integrate the Mk 7 Antipersonnel Obstacle Breaching System onto iRobot's 710 Warrior robot chassis. The operational vignette was initially configured as a route clearance scenario. However, the mission was broadened to include potential scenarios of crowd dispersal and engagement of enemy combatants (2009). Efforts continue with future integration of nonlethal weapons to provide a scaled response to imposing threats.

Unmanned Sea Vehicle (USV)
Sea-Based Defense

NAWCWD is developing numerous USV systems demonstrating cooperative autonomy between multiple USVs employing nonlethal weapons for seaport of debarkation, as well as gas and oil platform protection. Unmanned maritime patrol and intercept capability synergized with nonlethal weapon equipment provides security personnel added time to assess a threat at great distances. With the use of platform agnostic integration architecture, this capability prevents exposing manned vessels to potential threats during periods of uncertainty. Greater protection of U.S. high-value assets can be achieved through this layered defensive system. The process is as follows.

1. **Threat assessment.** The USVs autonomously and collaboratively assess incoming targets through equipped sensors. As the first defense layer, the USVs autonomously detect intrusion based on priority rule sets and call supervising human operators.

2. **Sound and light warning engagement.** Next, human operators manually engage the nonlethal weapon directed sound and light array (DSLA). The USVs autonomously maneuver to focus the DSLA to illuminate and warn nonhostile intruders.

3. **Firing of flash-bang and flare-bang.** As the third defense layer, human operators fire flash-bang and flare-bang nonlethal weapon rounds to further demonstrate intention to deter intruding vessels by clouding the operator's vision. As intruding vessels continue past these increasing warning levels, aggressive intent is established and human operators will engage and defend as appropriate.

UxS Testing and Evaluation (China Lake and Point Mugu)

Global Hawk Transcontinental Flight (2008)

NAWCWD supported the first FAA-authorized Global Hawk transcontinental flight from Patuxent River, Maryland, to Point Mugu to support Trident Warrior '08 and Rim of the Pacific (RIMPAC) '08.

GPS-Guided GBU-49 (2008)

NAWCWD personnel supported an exercise in which the 658th Aeronautical Systems Squadron test team completed the first live releases of the GPS-guided GBU-49 weapon from an MQ-9 Reaper at the China Lake Land Ranges.

GPS-Guided Weapon Release From Unmanned Aircraft (2004)

The Land Ranges hosted the first test of a GPS-guided weapon released from an unmanned aircraft when an X-45A technology demonstrator for the J-UCAS program dropped an inert GPS-guided SSB, which successfully hit a ground target.

Griffin Air-to-Surface Missiles Weaponization for Predator (2009)

NAWCWD began testing Griffin air-to-surface missiles for integration onto the Predator using the Hellfire interface and performed both live and inert drops of JDAMs from the Predator.

iRobot Crowd Control Demonstration (2010)

NAWCWD engineers and the iRobot Corporation conducted a successful demonstration/simulation exercise in which unmanned ground and air vehicles worked together to effectively disperse a simulated crowd of people. First, the remote UAV ScanEagle and Raven, flying overhead, identified the crowd/problem and communicated that information to the ground team, who then loaded the iRobot 710 Warrior robot chassis with Venom V-10, a nonlethal tube-launched munitions system that provides coverage at near, mid, and extended ranges. Once within range, the unmanned iRobot launched nonlethal flash bangs, smoke rounds, sting balls, hailers, combination rounds, and long-range warning signals to disperse the "crowd." This experiment proved the effectiveness of using several unmanned platforms to collaboratively address a problem.

Pegasus X-47A (First Successful Flight) (2003)

China Lake personnel provided key support of the first flight of a Northrop Grumman Corporation Pegasus experimental UAV in 2003. In this successful exercise, which took place on the China Lake Land Ranges and lasted 12 minutes, the Pegasus landed near a predesignated touchdown spot that simulated the tail hook arrestment point on a carrier flight deck.

Predator A UAV Weaponization (2005)
An MQ-1 weaponized Predator A scored several direct hits with Hellfire missiles on simulated enemy targets located on the China Lake Land Ranges.

Predator UAV Weaponization With Hellfire (2001)
The Hellfire missile was integrated and tested with the Predator UAV on the NAWCWD Land Ranges before being sent in theater to support the Warfighter in the War on Terror. In February 2001, an Air Force Predator 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.

ScanEagle First Flight (2008)
The successful initial flight of the first unmanned ScanEagle test vehicle owned by the Navy took place on the China Lake Land Ranges.

Vigilante UAV Weaponization With Spike (2008-2009)
In 2008, the Vigilante UAV completed a captive-carry flight with a Spike missile, which was 25 inches in length and 2.25 inches in diameter and weighed 5.3 pounds. In 2009, Spike was fired for the first time from a UAV using the NAWCWD-developed UAV-capable AFCS. In that event, when test engineers fired Spike from the top of a small mountain, the missile made a direct hit of a moving target nearly a mile and a half away on the valley floor. These tests demonstrated Spike's ability to acquire and track targets while being remotely operated. Both Spike tests also successfully demonstrated the UAV-capable AFCS developed by NAWCWD.

China Lake UxS Facilities and Equipment

This publication has an entire chapter devoted to laboratories and facilities. Therefore, this section highlights only those facilities that conduct significant UxS work. Most facilities are multipurpose and serve a wide variety of DoD needs.

Flash Site UxS Facilities
NAWCWD must maintain the ability to conduct a broad range of air and land test and training operations and activities that support warfighter requirements and provide the decision-quality data required to support UxS mission areas. Flash Site, within the ECR, provides an environment to consolidate UxS RDT&E tactical and small tactical systems with expeditionary ground systems for a more efficient integrated capability. During fiscal year 2010, Global Hawk was the top user of ECR, logging more than 200 flight hours.

Integrated Battlespace Arena (IBAR)
The IBAR is an advanced simulation facility. Nine interconnected laboratories and facilities provide simulation and analysis—from the subcomponent to theater levels—with a degree of fidelity, flexibility, and dependability unparalleled in the DoD. Facilities are linked worldwide with multiple

fiber-optic networks, including the SIPRNET and DREN. In addition, the complex offers extensive range microwave telecommunication capabilities.

Mobile Command and Control Laboratory (MCCL)

The MCCL is a freightliner business class M2 truck, a configuration that allows for remote testing (launch, recovery, and mission) of unmanned ground and air platforms. This facility is equipped with command and control radios and is designed to support the integration of any test platform or equipment. This self-contained and self-powered laboratory is capable of providing data distribution over multiple networks.

Payload Integration Laboratory

The Payload Integration Laboratory maintains a complete remote operations center and electronics laboratory, including state-of-the-art spectrum and signals processing equipment, and is capable of conducting missions or simply mirroring actual operations of the MCCL. Facilities include a complete suite of electronics tools, to include oscilloscopes, spectrum analyzers, and soldering stations.

Rapid Prototyping Facility

The Rapid Prototyping Facility, a 9,000-square-foot complex located at the China Lake airfield, is designed to support rapid prototyping of all types, tactical wheeled vehicles, aircraft, and subsurface craft. The facility can handle classified projects as needed and can house small- to medium-sized vehicles for any modifications required when customers come to China Lake for weapons test and validation.

The Rapid Prototyping Group provides select weapons engagement zones for emerging low collateral weapons suitable for Group 1 through Group 5 UAVs and involves coordination with the weapon prime contractors and program managers. Work includes running 6-degree-of-freedom simulations to calculate the probability of hit and probability of kill of tactically representative shots against varying targets. NAWCWD also conducts weapon evaluations and tactics for all UAVs. These data are the backbone of tactical concept of operations for UxS, which have a primary ISR mission and must be capable of immediately engaging high-priority hostile targets. Comprehensive analysis data are used to quickly develop unmanned prototypes for rapid deployment when urgent warfighter needs arise.

Runways

China Lake has three runways: 14/32 is 9,103 feet long; 21/03 is 9,992 feet long and is equipped with arresting gear; and 26/08 is 7,702 feet long and is also equipped with arresting gear. China Lake also has a dedicated 2,200-foot-long unmanned airstrip that is combat aircraft loading area enabled.

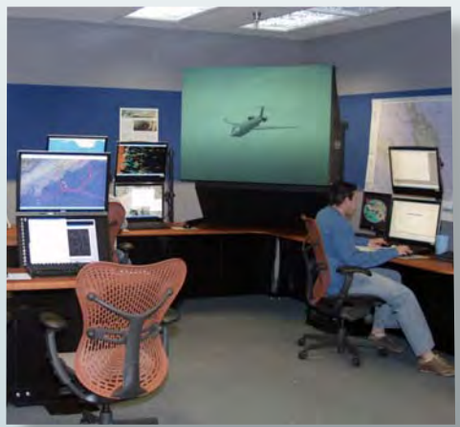
Software Engineering Laboratory

The Software Engineering Laboratory is ideally suited for developing and testing software, with complete life-cycle analysis in mind. Weapons racks and platforms are available for safety and end-to-end testing. Common control system development, prototyping, test, and evaluation are currently under way.

Systems Integration Laboratory

The Systems Integration Laboratory is a 14,000-square-foot building that is currently occupied by a premiere Air Force UxS activity responsible for payload, systems integration, and weaponization of tactical persistent and penetrating unmanned air system.

Unmanned Systems Facility (USF)

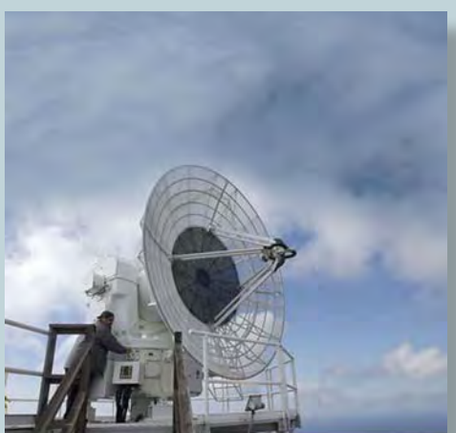


The USF can simulate all aspects of UAS in flight, including command and control sensor integration. The facility is an ideal test bed to rehearse combat scenarios; refine processes for collecting, recording, and handling data; evaluate sensors and data links; and identify critical events prior to live testing. All USF models are higher level architecture and distributed interactive simulation compliant and easily integrated with other IBAR or live assets. The backbone of the USF is the Multiple Unified Simulation Environment (MUSE)/Air Force Synthetic Environment for Reconnaissance and Surveillance (AFSERS) UAS suite—developed under the auspices of the Joint Technology Center/Systems Integration Laboratory at Red Arsenal—which simulates flight characteristics of most military UAS. MUSE also includes a control station surrogate featuring maps, data links, and vehicle controls.

Equipment/Instrumentation

China Lake operates and maintains a full suite of instrumentation for T&E, including those for radar tracking, telemetry, photo-optics and video, land and air surveillance, voice communications, and data processing and displays. Instrumentation is available across both the North Range (R-2505 and R-2506) and South Range (R-2524). These ground-based assets include the Navy's largest dedicated electronics warfare range. Real-time data transfer with other DoD and contractor facilities is available through multiple fiber connections, as well as via wireless data links, at most test sites.

Data Links and Communication Systems



System Engineering/Analysis

- Communications Paths/Networks Types
- Communication Relays
- Blue Force Situation Awareness
- Integration With Ground Forces Tools/Equipment/ Systems

Component Engineering—PSS-SOF

Modeling and Simulation (M&S)

- Data Rates/Sharing
- Data Types/Resolution

- Payload Control/Re-tasking
- Communications Relay

Operational–Virtual Environment
- Networking
- Link Encryption

Land Range Real World Verification
- North Range—RF Spectrum Isolation
- Spectrum Issues/Frequency Management

Integrated Fleet Operations
- Joint Exercises
- Special Operations Forces

Tracking and Surveillance Systems
- Fixed and Mobile Telemetry
- EW Systems
- Radars
- Spectral Characterization
- Optical Systems

Navy Target Systems
China Lake is the Navy lead for the development and operation of Land Range targets in support of the Fleet, DoD, and foreign military customers. This role includes development and production of EW threats for tactical training ranges, moving/relocatable threats/targets, missile plume simulators, shootable RF threats/targets, laser threats, GPS jamming, and hostile fire indication testing.

Point Mugu UxS Facilities and Equipment

Coast Guard UAV Facilities
NAWCWD, the 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 multiyear, multiphase effort to replace 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; NAWCWD has the engineering capabilities to outfit the UAVs with the specialized sensors and instrumentation required for the Coast Guard mission. In addition, the UAVs that are housed in the existing hangar on the flight line would have immediate access to the operational and test areas, all within a secure, restricted airspace.

Runways

Point Mugu has an 11,000-foot-long primary runway, and San Nicolas Island has a 10,000-foot-long runway. Land masses at San Nicolas Island and Vandenberg AFB can also be used for emergency recovery.

San Nicolas and Santa Cruz Offshore Islands

San Nicolas Island provides a platform ideally suited for testing in the marine environment. It approximates a shipboard platform, but with all the advantages of a mainland test site. Land recovery in small or remote areas may be performed. In addition, launch and recovery aboard small surface craft or ships up to the destroyer class may be performed. The San Nicolas and Santa Cruz offshore islands offer dedicated hangars, launch pads and surface craft, and chase aircraft.

Equipment/Instrumentation

Point Mugu operates and maintains a full suite of instrumentation for T&E, including tracking radar, telemetry, photo-optics and video, sea and air surveillance, voice communications, and data processing and displays. Instrumentation is available at Point Mugu, Laguna Peak, San Nicolas Island, and Santa Cruz Island. These ground-based assets are augmented by airborne instrumentation aboard NP-3D Orion aircraft to ensure effective data collection over the entire 36,000-square-mile range. Real-time data transfer with other DoD and contractor facilities is available. An extensive library of real-time and post-flight data products is available on almost any media. Customized displays and data products are available.

Tracking and Surveillance Systems

- Tracking and control rooms including real-time graphics systems, data display, and naval tactical data systems
- "Hybrid" Furuno surface surveillance radar
- Cast Glance (stabilized P-3 or A-3 airborne photo-optical system)
- Data links to other long-range surveillance radars at Vandenberg, San Clemente Island, and San Pedro
- Three P-3A aircraft for airborne telemetry (numerous range aircraft and surface craft are available to support UxS T&E)

Data Links and Communication Systems

- Link-16 terminal at San Nicolas Island and antenna set at Point Mugu
- Air Defense System Integrator
- Link-16, 11, 4A
- DREN
- Defense Information System Network–Leading Edge Service
- Tracking and Data Relay Satellite System
- Secret Defense Research and Engineering Network (SDREN)
- Networked Capabilities, such as Global Command and Control System–Joint, Global Command and Control System–Army, Maritime Operations Center, Command Air Operations Center

Navy Target Systems

Point Mugu is the development, engineering, and logistic support organization for all Navy target systems. This role includes support of air and surface targets: QST-35/35A, HSMST, MST, Robo-ski (Jet Ski), and fast attack boats. Reconnaissance targets for UxS support include passive IR and electrooptical resolution charts, various ship classes, and several land-based targets that include vehicles and airfields; EW and electromagnetic threat environments; and countermeasures, such as airborne jammers and simulators, chaff, flares, expendable countermeasures dispensers, and surface emitters.

NAWCWD Leadership in UxS Battlefields of Tomorrow

Engineers are immersed in the evolutionary planning stages for intelligent UxS. Future machines will be able to assimilate and evaluate vast amounts of information, transmit pertinent information to a human counterpart, and then determine and take the appropriate actions, thus eliminating the need for humans to conduct analysis and make decisions. The machines of tomorrow can determine much more quickly than humans the best way to prosecute targets, such as establishing what kind of weapons and vehicles can be used and what tack has the greatest possibility of success—even factoring in the probability of risks and level of collateral damage. Future warfighters are likely to have personal UxS at their control—either carried or mounted on their vehicle—such as items that pop up, look around, and perform a wide variety of surveillance functions. New technologies will extend the warfighters' senses—their eyes and ears. A technology for UxS that is currently on our doorstep is the sense-and-avoid safety systems now being used in the automotive industry.

Scope of Operations/Customers

- **Government:** Air Force; Army Program Manager for UAS; Department of Homeland Security; Department of Interior; Department of Justice; FBI; USJFCOM; Joint UAS Data Information Exchange; Joint Unmanned Air Systems Center of Excellence; Marine Corps Special Operations Command; Missile Defense Agency (MDA); Naval Special Warfare (NSW); Naval Surface Warfare Centers: Dahlgren, Dam Neck, Newick, and Carderock; Naval Undersea Warfare Center; Program Executive Officer Unmanned Aviation and Strike Weapons [PEO(U&W)] PMA-262 (Persistent Maritime Unmanned Aircraft Systems), PMA-263 (Navy and Marine Corps Small Tactical Unmanned Aircraft Systems), PMA-266 (Navy and Marine Corps Multi-Mission Tactical Unmanned Air Systems), PMA-268 (Unmanned Combat Air System Demonstration); Program Manager Joint Attack Munitions Systems

- **Private Industry:** AeroVironment, Inc.; Boeing Company; GE Aviation Systems; General Atomics Aeronautical Systems, Inc.; Lockheed Martin Corporation; Northrop Grumman Corporation
- **CRADA Partners:** ATK; DreamHammer, Inc.; GTA; iRobot Corporation; MBDA Inc.; Northrop Grumman Corporation; Raytheon Company
- **Academia:** Auburn University; Massachusetts Institute of Technology; Naval Postgraduate School; Stanford University; University of California Los Angeles; University of Colorado, Boulder; University of North Dakota; University of Southern California; University of Wyoming

Immense Interconnected, Un-encroached Land and Sea Ranges for UxS RDT&E

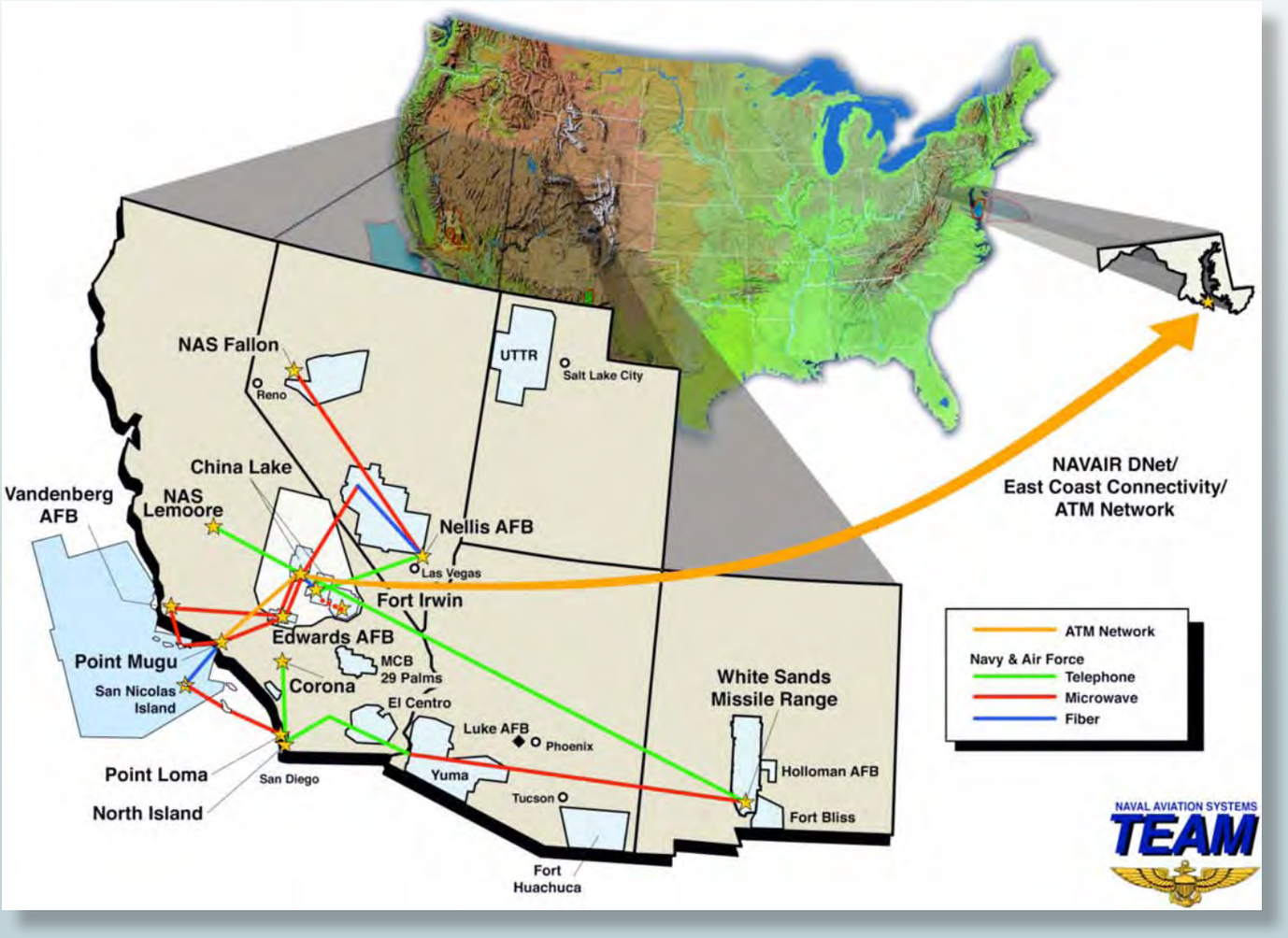
Enormous Ranges

NAWCWD's land, sea, and airspace are unique natural assets and are used for extensive training and T&E. Additional sites in the local area include the Naval Ship Weapon Systems Engineering Station, Port Hueneme; the Western Space and Missile Center, Vandenberg AFB; and Yuma Proving Grounds, Yuma, Arizona.

Interconnectivity

With its efficient processes for joint spectrum monitoring, NAWCWD is able to support more UAV operations in cooperation with other DoD and FAA activities. Network connectivity is often established between the IBAR and the Land and Sea Range complexes. Through the IBAR, the USA is able to connect to virtually any DoD or commercial network. Common UxS commercial connections include connectivity to iRobot Corporation, Medford, Massachusetts, and Insitu, Incorporated, Hood River, Washington. West Coast neighbors that work closely with NAWCWD include the Air Force (Edwards, Holloman, Luke, Nellis, Vandenberg), the Army (Fort Bliss, Fort Huachuca, Fort Irwin), the Navy (NAS Fallon, NAS Lemoore, NAS North Island, Space and Naval Warfare Systems Command), and the Marine Corps (Marine Corps Tactical Systems Support Activity).

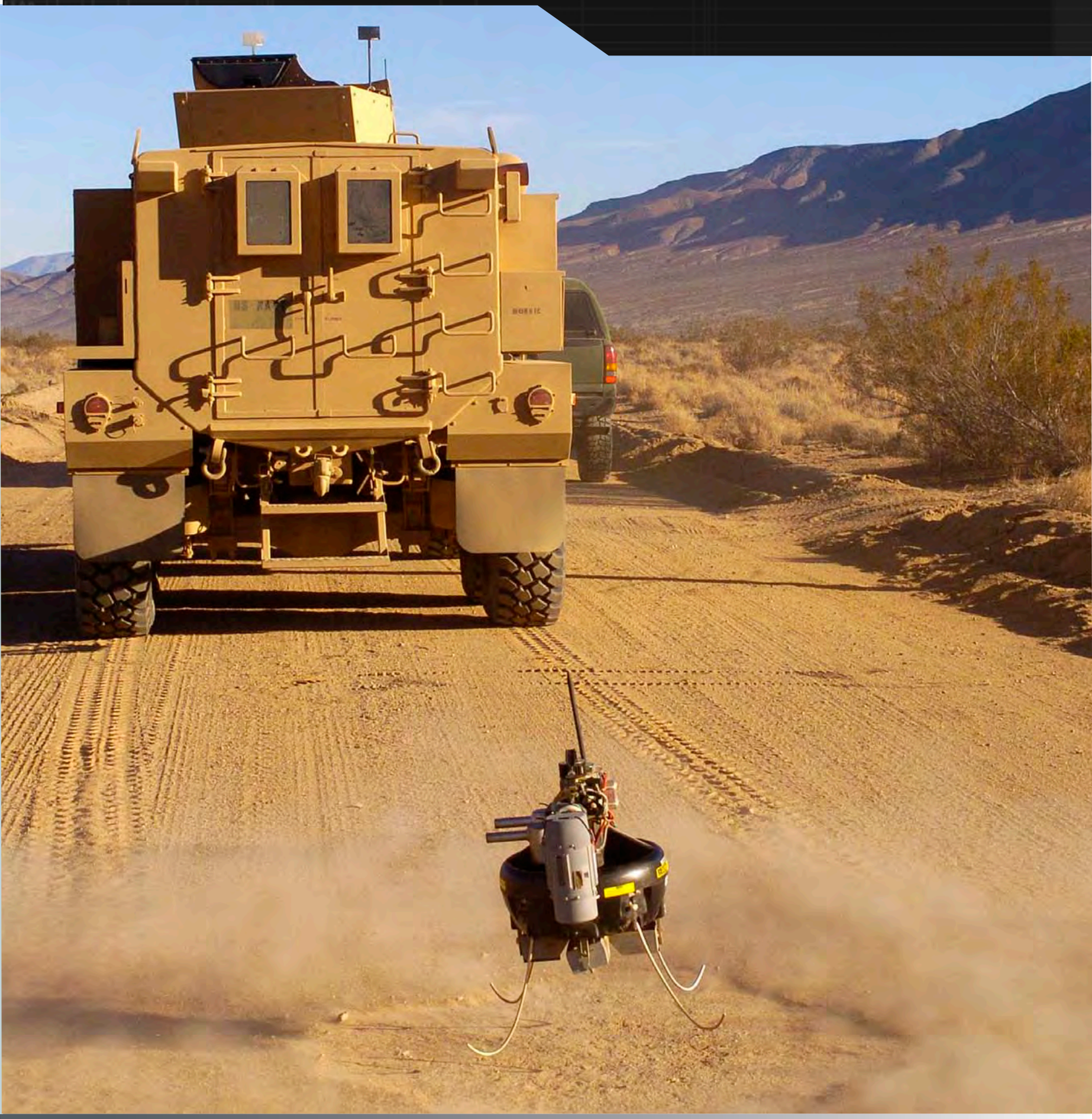
Western Test and Training Range Connectivity



“If there is to be another war, the shape of it will be visualized here at China Lake. Each time I come here, I have an impression that I am being given a look into the future. Here, many of the weapons of the next war will have taken shape first in the minds of some of you now present.”

—John Nicholas Brown
Assistant Secretary of the Navy

Test and Evaluation (T&E)



Test and Evaluation (T&E)

Each year, NAWCWD conducts more than 1,500 test events, hundreds of major training events, and approximately 35,000 training sorties within the R-2508 complex. NAWCWD evaluates weapons, components, and systems in realistic environments; conducts full-scale joint live fire survivability testing; and tests guns and ammunition, explosives, and propellants. NAWCWD maintains the world's largest collection of "shootable" ARM targets for test activities. Because of its isolated ranges, NAWCWD can safely detonate up to 500,000 pounds of explosives. Tests are also done on GPS jamming, high-power microwaves, and firefighting agents and devices. Parachute testing was an important test function performed at China Lake, which served as the National Parachute Test Range from 1979 through 2005.

Test Squadrons

NAWCWD is the home of several Navy test squadrons that help in T&E efforts. These squadrons are essential to the development of missiles and weapon systems at NAWCWD, as well as being instrumental to the Warfighter.

VX-30 and VX-31 operate under the command of the Naval Test Wing Pacific (NTWP), which reports to the Commander, NAWCWD. Both squadrons provide aircraft, aviators, and aircrew to support the RDAT&E mission on NAWCWD's Air, Sea, and Land ranges. NTWP's 278 military and civilian employees, along with 400 aircraft maintenance contractors, allow squadron pilots to log more than 7,800 hours of testing and training missions annually.

VX-30

The VX-30 "Bloodhounds" operate a diverse inventory of instrumented Navy range support aircraft and support many developmental programs, including the F-22 Raptor, Sidewinder AIM-9X, EA-6B Prowler, Tactical Tomahawk Land Attack Missile, AMRAAM, HARM, and SLAM-ER. VX-30 also supports high-profile scientific and strategic customers, such as NASA, MDA, and U.S. Air Force ICBM improvement programs.

VX-30 operates additional aircraft, including the F-18A/B Hornet, F-14A/B/D Tomcat, QF-4N/S Phantom, LC-130F,

DC-130A, and KC-130 Hercules. Operational testing includes the ITALD II, F/A-22 Raptor, and Sidewinder AIM-9X. The final VX-30 flight of the F-14 Tomcat took place in 2006, marking an end to an era, and the final QF-4 flight took place as Bloodhound 145 was flown to NAS North Island to become a display in the USS *Midway* museum in San Diego.

In 2006, 12 VX-30 personnel were deployed to Iraq, Afghanistan, and the Horn of Africa as individual augmentees. More than 2,100 sorties were flown, and VX-30 supported multiple SLAM-ER, Tomahawk, AMRAAM, and Phalanx test flights, as well as Sea Harrier, ATFLIR devices, and several other projects with VX-30 F/A-18s. [173]

VX-31

The VX-31 "Dust Devils" have operated F/A-18A-F Hornets/Super Hornets, AV-8B Harriers, HH-1N Hueys, AH-1W Cobras, T-39 Saberliners, and SA-227 Metroliners. A variety of warfighting improvement programs were supported on all platforms. VX-31 has flown more than 2,787 total sorties, with 4,802 flight hours in support of aircraft and weapons programs.

The APG-79 AESA radar for the F/A-18E/F was one of the major programs supported by VX-31 in 2005, and OPEVAL began. The squadron returned to flight mission duty for the Space Shuttle Discovery, and one VX-31 crew staged a Huey at Edwards AFB in support of the shuttle's return. In addition, VX-31 provided range support and T&E for a revolutionary new network centric warfare tool called the Tactical Targeting Network Technology (TTNT). TTNT was designed to enable all entities in the battlespace to provide nearly real-time information, including video, to the Atlantic Ocean Region Commander to reduce the kill chain reaction time. In 2005, 140 personnel from the Navy, Air Force, and DoD civilian and contractor communities descended on China Lake to test the new wireless system. More than 500 VX-31 man-hours and 25 flight hours were dedicated to this project.

During 2006, the squadron continued developmental test of current and future combat aircraft, weapons, and associated weapon systems and provided enhanced combat capabilities for the F/A-18A-F Hornet, AV-8B Harrier, and AH-1W Cobra platforms. VX-31 welcomed the arrival of the AH-1Z Cobra and UH-1Y and the EA-18G Growler. At the close of 2006, VX-31 was actively supporting 35 separate developmental T&E projects for weapons, aircraft, and associated systems. [174]

VX-9

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. The VX-9 "Vampires" conduct operational T&E of all air-to-ground weapons, air-to-air weapons, sensors, EW systems, and mission software upgrades to aircraft and weapon systems. More than 350 VX-9 personnel maintain and fly a diverse fleet

of approximately 20 aircraft used in the demanding and dynamic role of operational flight test in support of both Navy and Marine Corps tactical aviation. VX-9 currently operates and tests the F/A-18E/F Super Hornet, F/A-18A-D Hornet, AV-8B Harrier, EA-18G Growler, and EA-6B, as well as the AH-1W/Z Cobra and UH-1Y helicopters. The squadron logs more than 3,800 flight hours annually and is a tenant of NAWS at China Lake.

During Operation Enduring Freedom in late 2001, VX-9 performed a quick-reaction assessment for the GBU-32 1,000-pound JDAM. Eight test missions were conducted, and VX-9's efforts resulted in rapid fielding. In addition, VX-9's testing on ISR programs such as SHARP, ATFLIR, and LITENING II has given Navy and Marine Corps platforms an increased capability to counter IEDs and support troops in enemy-controlled territory. Also during Operation Enduring Freedom, VX-9 finished Hellfire quick-reaction testing in only 4 weeks, normally a 4-month or longer operation.

Marine Aviation Detachment (MAD)

Although the MAD's headquarters were established in 1987, Marines have been stationed at China Lake since 1943. The detachment operates under the command of the Aviation Department, Headquarters, Marine Corps.

The mission of MAD is to provide project management, aviation support, technical expertise, and Fleet support for assigned Marine Corps weapon systems and related devices throughout the weapon systems' life cycle. MAD accomplishes this objective by supporting developmental and operational testing at VX-31, VX-9, and elsewhere and by providing warfighter input to the engineers and support personnel of NAWCWD through Marines who are based at China Lake and Point Mugu. MAD also provides project management, aviation support, and technical expertise for assigned Marine Corps weapon systems and subsystems, as well as mission planning at both China Lake and Point Mugu.

The MAD works diligently to ensure that those who go into harm's way receive nothing but the most reliable and effective weapon systems available and are ready for any major regional contingency. MAD responds to Fleet needs as the operating forces continually refine tactics, techniques, and procedures to increase mission effectiveness and enhance force protection against an evolving set of threats.

Land Range T&E Efforts

The size, location, and environment of the NAWCWD Land Ranges make them ideal for T&E efforts. While it would be impossible to discuss each significant accomplishment in this document, several NAWCWD Land Range T&E efforts are worth mentioning.

Empire Challenge

China Lake hosted the Empire Challenge exercise from 2004-2009. Empire Challenge was a 2-week exercise to demonstrate and evaluate intelligence-gathering techniques and joint and coalition warfighting operations. The exercise initially hosted approximately 700 people from Great Britain, Canada, and Australia who brought a large-scale multinational military force to China Lake, including aircraft, sensors, equipment, and personnel. By 2009, however, Empire Challenge evolved to more than 1,500 civilian and military personnel at China Lake and was being led by the National Geospatial-Intelligence Agency, partnering with the National Reconnaissance Office and the USJFCOM.

Empire Challenge used numerous key NAWCWD assets extensively, such as the Airspace Surveillance Center and the Range Signal Density Enhancement Team at the ECR. The goals of each Empire Challenge have focused on specific exercises important to the Fleet at that time. For example, during the 2007 Empire Challenge, exercises demonstrated joint and coalition interoperability among ISR platforms, sensors, and systems. The idea for the exercise was developed after combat operations in Iraq and Afghanistan identified technical issues with the sharing of ISR information with allies. This was the largest and most-complex series of ISR system tests and technology in that it combined real-time surveillance with preplanned and nontraditional reconnaissance, using a worldwide network to reach back and collaborate with allies in Australia; Canada; Great Britain; and the NATO Consultation, Command, and Control (NATO C3) Agency. Ground operations tested manpower and equipment simulating real-life situations in theater, including convoy attacks by opposing forces, small arms fire, and IEDs. Imagery intelligence and ground moving target indicator (MTI) data were data linked in real time. The data were screened and relayed via a Global Broadcast Service uplink to receiving stations at the Royal Air Force Marham in England; the Defense Imagery and Geospatial Office in Canberra, Australia; and the Canadian Forces Defense Headquarters in Ottawa, Canada. Analyzed and exploited intelligence data products were then sent from those long-distance locations back to China Lake on a secure network. [172]

Enterprise Expeditionary Strike Warfare Architecture (eESWA)

A U.S. Navy and industry team completed the successful demonstration of the eESWA, an advanced targeting and strike capability that will drive the requirements for network centric strike systems of the future. The experimental demonstration showcased 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 at the Precision Engagement Center at China Lake, brought together for the first time an integrated, open architecture for ISR; time-critical targeting; and strike mission planning and execution. This demonstration was the first time the Navy had brought together so many capabilities in a horizontally integrated, open architecture and represented a tremendous step forward in determining the forward-looking strategy for programs like Joint Service Imager Processing System and the Distributed Common Ground Station. [63]

Fast Cookoff Testing

During the 1960s, the U.S. Navy experienced major aircraft carrier disasters aboard USS *Oriskany*, USS *Forrestal*, and USS *Enterprise*; each accident was 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 by using thermocouples and time-to-reaction instrumentation. Attempts were later made to test materials that would stretch the time between the onset of the fire and a violent reaction. The sophisticated technology necessary to understand the reaction of the ordnance, however, 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 2,000°F pool fire, blast from a rocket motor exhaust plume, and blast and fragmentation from a rocket motor blowup. 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 2,000-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]

Joint Expeditionary Force Exercise 2006 (JEFX06)

JEFX06 was a highly focused multinational, multiservice experiment designed to rigorously assess and make recommendations on selected capabilities in the battlespace. The exercise focused on continuous theater planning and dynamic execution, as well as goals from the Department of Homeland Security; operations were successful in all objectives.

During the exercise, simulated tracks and images were transmitted from the IBAR at China Lake to the Global Hawk Maritime Demonstration (GHMD) Tactical Auxiliary Ground System at

Patuxent River, Maryland, where tracks were nominated into the Commander, 2nd Fleet Common Operational Picture, and images were chipped and posted to the Imagery Transformation Services website. GHMD was also used to develop and refine concept of operations, tactics, techniques, and procedures, while providing maritime operational and intelligence data to various homeland security/homeland defense nodes.

Rapid Airborne Mine Clearance System (RAMICS)

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 farther up the hill was an AH-1F Cobra gunship with its M197 20-millimeter Gatling gun pointed 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-millimeter Gatling gun. This effort was sponsored by the ONR and was directed from the Naval Surface Warfare Center Dahlgren Division's Coastal Systems Station. [113]

Shootable Remote Threat Ground Target (SRTGT)

In 2007, the SRTGT Project Team completed the design of a Ford F350 target vehicle that incorporated a scoring system, a TSPI system, a laser emitter, and a trailer and towed target system. The team also increased speed capability to 90 miles per hour. Limited production of the target has started for a variety of uses. [172]

Supersonic Naval Ordnance Research Track (SNORT) Upgrade

In 2007, China Lake modernized the 50-year-old SNORT's recording and controller system from legacy to analog data over solid-copper control lines to state-of-the-art digital controllers riding over dedicated fiber-optic cables. This upgrade involved installing more than 14 miles of direct buried fiber-optic cable, terminating in 47 different points along a 6-mile track. [172]

Shortly after the upgrade, China Lake conducted a successful Mk 70 drag run at SNORT. This was the second firing run after finishing the SNORT upgrade. SNORT used an existing sled that was powered by two Mk 70 solid rocket motors to obtain a thrust profile for a propulsion motor that was recently added to its inventory. The successful firing produced a velocity of higher than Mach 2. The velocity was monitored by various instrumentations devices, such as a velocity measurement system and a tracking mount. The data were measured at 100-foot intervals along the main 4.1-mile track. At shorter intervals, there were portable tracking systems, which were

used to determine the barriers involved in testing, as well as for protection upon the accidental release of weapons. Over the course of 50 years, SNORT has logged more than 9,000 track test runs. [177]

Sea Range T&E Efforts

The NAWCWD Sea Range is significant to T&E efforts for sea tests. The range has offered an extensive array of testing capabilities, which helped provide the Warfighter with a strategic advantage.

Combat System Ship Qualification Trial (CSSQT)

In 2006, the Sea Range conducted the first-ever triple ship developmental and operational test event that included USS *Mobile Bay*, USS *Halsey*, and SPS Blas de Lezo (Spanish Navy Airborne Early Warning Ground Integration System [AEGIS] frigate), an effort that covered a wide range of T&E requirements. In addition, aerial and surface littoral T&E operations were conducted in both tracking and live fire environments. This event concluded with the largest-ever surface warfare layered defense live fire operational test event against the largest number of simultaneous remotely controlled surface targets. In addition to dozens of manned aircraft and electronic target raids against the three ships, more than 30 Standard Missiles were launched and more than 50 subsonic and supersonic aerial targets were presented for tracking and firing events. This trial included the first operational GQM-163A Coyote Supersonic Sea-Skimming Target missile exercise and culminated in the largest number of simultaneous BQM-74 targets. These exercises are called "trials" because the job is tough, relentless, and designed to bring out the truth about the ship's readiness to go to war.

In one trial, USS *Mobile Bay* was fitted with the latest in combat systems—guns, missiles, and radars, as well as a host of other weapon and weapon-related equipment, including vertical launch systems for Tomahawk, Standard Missile, and ASROCs. Also included were 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 USS *Mobile Bay*'s offensive and defensive capabilities was the AEGIS, built around an advanced automatic detect-and-track multifunction phased-array radar called the AN/SPY-1. This high-powered radar handled search, track, and missile guidance functions, all simultaneously, with a tracking capacity of more than 100 targets. Those systems and the men and women who operate them were then qualified to the most rigorous standards of proficiency. [54]

Five target scenarios were presented by Sea Range personnel using two BQM-74Es, one BQM-34S, one AQM-37C, and one Vandal Extended Range. NAWCWD personnel at Point Mugu raised the

stress level considerably during this trial when they conducted multiple manned aircraft raids against USS *Mobile Bay*, with each of the aircraft realistically simulating an incoming threat. NAWCWD flew multiple tracking missions with Q-Lear and NKC-135 electronic attack aircraft. Two BQM-74E aerial targets flew five tracking presentations over and near San Nicolas Island to exercise the AEGIS combat system's capability to track and engage antiair warfare threats in a high-clutter littoral environment.

Another successful CSSQT was conducted at Point Mugu in 2007. In 2010, the United States Navy and the Spanish Navy again conducted a CSSQT to demonstrate the fighting capabilities of the AEGIS combat system. At this time, USS *Dewey*, USS *Wayne E. Meyer*, and the Spanish Navy frigate Alvaro de Bazan were involved. During the trials, the AEGIS was successfully evaluated for combat readiness and air defense capabilities through a series of comprehensive exercises, including manned raids and electronic scenarios. [4]

Deployable Homeland Airborne Cruise Missile Defense (DHACMD)

In 2006, NAWCWD provided the facilities and the communications infrastructure required by more than 300 deployed military personnel working tactical operations on the beach at Point Mugu for the DHACMD joint exercise proof of concept. The exercise was driven by North American Aerospace Defense Command, U.S. Northern Command, and 1st Air Force to demonstrate an integrated air defense system. The exercise included an Aegis ship, a Patriot missile battery (no live Patriot firings), several air defense sensors, and a Joint Based Expeditionary Connectivity Center. Many manned aircraft and unmanned BQM-74 targets were presented as threats over an intensive 2-day period, in addition to target presentations and Sea Range coordination. [172]

Extended Area Test System (EATS)

Started in 1972 and completed in the early 1980s, EATS was a multilateral tracking system that operated over the horizon in a 250-mile radius around San Nicolas Island. EATS could track up to 60 ships, aircraft, and targets from sea level to 100,000 feet, as well as 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 communicated with instrumentation packages installed in drone targets, launch aircraft, and ships participating in test exercises. EATS was replaced by the Multilateration Operations Control System (MOCS), which 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]

Hydra

During the 1960s, Project Hydra studied the comparative methods for launching satellite, high-altitude probe, and rocket vehicles at sea. Because Hydra used 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 late 1960s, the first full-term multistage 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 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]

Missile Defense Agency (MDA)

In 2006, NAWCWD provided vital test planning, range instrumentation, and sensor management support to the ground-based midcourse defense system test, FTG-02, for MDA. The Pacific Range Support Team presented a realistic ballistic missile threat launched from Kodiak, Alaska, to the interceptor launched from Vandenberg AFB. This was the first successful exo-atmospheric kill vehicle intercept conducted on the U.S. West Coast. [172]

NP-3D Orion

The NP-3D Orion continued to traverse the globe, safely accomplishing its missions of range surveillance and area clearance, cast glance optical surveillance, and missile tracking. Aircraft were deployed to Hawaii on three separate occasions in support of the AEGIS Program and MDA. On the Sea Test Range, VX-30 P-3s assisted with NASA's Delta II (Gravity Probe B) and Pegasus, which were launched from Vandenberg AFB.

Orion crews supported numerous Sea Range test projects, including Tactical Tomahawk, Japanese Defense Force, Arrow, F/A-22 Raptor, SLAM-ER, Advanced Gunnery System, Fleet Joint Task Force Exercises, and AEGIS CSSQT events. [172]

Pacific Missile Range (PMR)

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. This effort included a fleet of heavily instrumented range ships (mostly converted World War II Victory ships) and aircraft (C-131 Constellations), all covering the broad Pacific area that had become a 5,000-mile "shooting gallery." At its peak in 1963, the PMR had more than 13,000 military, civilian, and contractor personnel onboard. Furthermore, operations were commanded by a rear admiral, with deputy commanders from the Army, Air Force, and Navy and representatives from the Marines and NASA. [153]

The Sea Range also provided crucial range safety and cast glance video data support to several U.S. Navy AEGIS Ballistic Missile Defense System tests conducted at PMRF. These tests validated the first-strike ballistic missile defense capability of the U.S. Navy in the Western Pacific. [172]

Air Range T&E Efforts

The NAWCWD Air Range allows the Navy squadrons stationed at NAWCWD to provide T&E support. Its restricted airspace allows the squadrons to fly unimpeded during T&E support. The extensive Air Range has also hosted numerous air exercises during its 60-year history.

Active Electronically Scanned Array (AESA) Testing

NAWCWD conducted extensive AESA testing during 2007. VX-31 used four production-representative F/A-18 Super Hornets and conducted 172 flight test events, generating 331 flight hours and more than 11,000 hours of ground and laboratory testing.

F-22

NAWCWD played a significant role in the development of one of the Air Force's most technologically advanced aircraft, the F-22. Because the platform required greater airspace to safely release guided missiles, the Air Force decided to focus its testing on the West Coast. NAWCWD provided the resources to perform a full spectrum of T&E services, especially weapons separation testing. NAWCWD acted as the primary agent for the integration of the Sidewinder onto the platform of the F-22 and became involved in EW and systems effectiveness.

An extensive IR signature evaluation, one of the largest of its kind ever performed, was completed at the 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 AFB enabled Combined Test Force members to see the test develop in real time. The NAWCWD IPT completed armament analysis and integration tasking, as well as supported the stand-up of the first operational squadron at Langley AFB. In 2009, however, Congress decided to end production of the F-22 in favor of the AirForce's F-35 aircraft.

Navy Combat Archer (NCA) Team

The NAWCWD NCA Team played a crucial role in a Fleet air-to-air missile exercise held at the Southern California Offshore Range. 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 TALD targets during this exercise. The NAWCWD 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.

Pegasus X-47A

China Lake personnel provided key support of the first flight of a Northrop Grumman Corporation Pegasus experimental UAV in 2003. In this successful exercise, which took place on the China Lake Land Ranges and lasted 12 minutes, the Pegasus landed near a predesignated touchdown spot that simulated the tail hook arrestment point on a carrier flight deck. NAWCWD has been involved in UAV and UCAV technology for several years.

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. The pod could carry a 70-millimeter sequential camera, 35- and 16-millimeter high-speed instrumentation cameras, and a television camera. The camera pod found extensive use in photographic surveillance of aircraft, missile launches, flights, and intercepts.

QF-4

In 2004, the VX-30 QF-4 Program at Point Mugu conducted an unprecedented 42 no live operator onboard full-scale aerial target events in a mere 8 months time. In total, seven aircraft were destroyed in support of live fire missile shots. The QF-4 fleet flew more than 167 hours in direct T&E support of projects such as AMRAAM, AIM-7, and AIM-9X for VX-9.

RQ-8A Fire Scout

In 2003, Northrop Grumman Corporation's RQ-8A Fire Scout vertical takeoff and landing UAV made two crucial technology demonstrations—flying with a SAR/MTI and completing initial at-sea testing aboard the amphibious transport dock USS *Denver*. During these trials, Fire Scout flew more than 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 Corporation. Fire Scout completed its second phase of at-sea testing, including flights out to the testing area from Point Mugu, where it made low-speed approaches to the USS *Denver* using the RQ-8A's Unmanned Common Automatic Recovery System and terminal control system. In 2007, the Fire Scout performed T&E activities on the MQ-8B.

“The personnel of VX-31 raised the benchmark for superior performance across the entire test community within the Navy. Deploying personnel to conduct combat operations and accelerating delivery of vital weapon systems for wartime use, the squadron demonstrated the highest levels of professionalism in their execution of mission accomplishment during Operation Iraqi Freedom.”

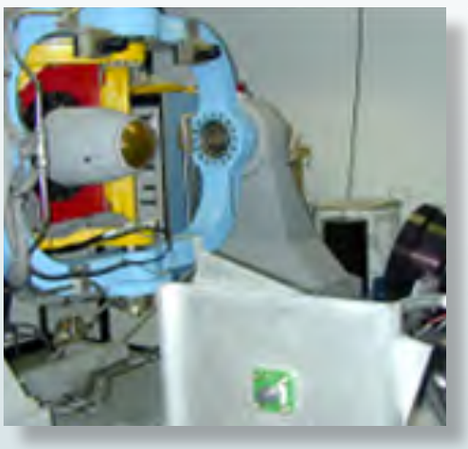
—Honorable Gordon England
Secretary of the Navy

“We are exploring the outer boundaries of science and technology, as well as the conventional aspects. We do not hesitate to direct our attention to what we believe will be the principles and practices of tomorrow, and we try to organize them in order to better direct the programs of today.”

—Dr. Royal Weller, first civilian Chief Scientist at NAMTC, Point Mugu

Modeling, Simulation, and Analysis

Modeling, Simulation, and Analysis



M&S play a major role in the integration process, thereby allowing continuous design assessment throughout the process. In the past, live fire testing was used exclusively to evaluate how a missile system functioned. NAWCWD, however, pioneered simulation-based acquisition, and its earliest use of M&S was in the creation of analog and digital simulations for weapon systems. The WSSA laboratories integrated advanced weapons and components into a total weapon system onboard naval aircraft platform.

Conducting M&S saves millions of dollars every years. Using HWIL simulators, NAWCWD 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 it would in actual flight. In the 1960s, the AIM-9D required 129 live firings to test its performance, but, by 1981, because of M&S, the AIM-9M required only 35 live firings. During the 1970s and 1980s, HWIL reduced the number of live firings required to field Sidewinder, Sparrow, and RAM. 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 less schedule impact.

Training is one important use of M&S. NAWCWD personnel 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. NAWCWD conducts complex "what if" battle group scenarios to analyze how well all the weapon systems integrate in real time. In 2002, NAWCWD completed the Millennium Challenge. The Sea and Land Ranges were the site of live action by joint forces. Efforts were orchestrated from the ITEC at Point Mugu and the IBAR at China Lake.

At China Lake's Superior Valley Range, there are tactical targets and automatic weapon scoring systems where NAWCWD trains pilots, including F/A-18 squadrons from Lemoore. NAWCWD also conducts search-and-rescue training and helicopter mobile assault training. On the ECR, pilots can fly against actual threat radar systems, fly HARM missions, practice tactics, and use countermeasures.

Navy and Marine assets throughout the continental United States often request and receive visits from NAWCWD personnel to provide training on advanced receiver operations and use of the mission planning update capability. In addition, each year, allied customers from many nations send hundreds of troops to train for conflict with test weapons on NAWCWD's ranges.

NAWCWD has been involved with numerous M&S systems and exercises through the years for training and weapons development. Those, along with several significant M&S programs and pertinent facilities, are discussed in the sections that follow. This publication has an entire chapter devoted to laboratories and facilities, which are multipurpose and serve a wide variety of DoD needs. Therefore, highlights are provided only for those that play a significant modeling, simulation, and analysis role.

Joint Fleet Training

Joint Fleet training is another important use of M&S. NAWCWD personnel can support anything from one aircraft on one target to complex battlespace scenarios involving multiple sites and multiple players. Fleet training exercises and FBEs are becoming increasingly complex. NAWCWD conducts complex "what if" battle group scenarios to analyze how well all the weapons systems integrate in real time.

On NAWCWD ranges, there are tactical targets and automatic weapon scoring systems where NAWCWD can train pilots during a JTFEX, including F/A-18 squadrons from Lemoore. NAWCWD also conducts search-and-rescue training and helicopter mobile assault training. On the ECR at NAWCWD, a vital range for the Warfighter, pilots can fly against actual threat radar systems, fly HARM missions, practice tactics, and use countermeasures. Also at the ECR, NAWCWD personnel supported a JTFEX involving USS *John C. 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]

Navy and Marine assets throughout the continental United States often request and receive visits from NAWCWD personnel to provide training on advanced receiver operations and use of the mission planning update capability. In addition, each year, allied customers from many nations send hundreds of troops to train for conflict with test weapons on NAWCWD's ranges. Several training exercises conducted at NAWCWD are discussed in the sections that follow.

Joint Expeditionary Force Exercise 2006 (JEFX06)

JEFX06 was a highly focused multinational, multiservice experiment designed to rigorously assess and make recommendations on selected capabilities in the battlespace. The successful operation focused on continuous theater planning and dynamic execution, as well as goals from the Department of Homeland Security.

During the exercise, simulated tracks and images were transmitted from the IBAR at China Lake to the GHMD Tactical Auxiliary Ground System at Patuxent River, Maryland, where tracks were nominated into the Commander, 2nd Fleet Common Operational Picture, and images were chipped and posted to the Imagery Transformation Services website. GHMD was also used to develop and refine concept of operations, tactics, techniques, and procedures, while providing maritime operational and intelligence data to various homeland security/homeland defense nodes.

Millennium Challenge 2002 (MC02)

In 2002, 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 USJFCOM, the experiment brought together the four military services, U.S. Special Operations Command, and most functional/regional commands, as well as many Weapons Division 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 incorporated ground, air, and sea capabilities among the services for mutual support, as well as to achieve a common operational picture. In a China Lake laboratory, the Weapons Engagement Office (WEO) built a Strike Warfare Command Center (STWC). This cell mimicked a carrier command center bearing the call sign of Alpha Papa. In addition to a staff of about 30 uniformed personnel manning the STWC, there were about 20 civilian technical representatives. Five people from the WEO worked with the experiment full time. The office also sent technical support to USS *Coronado*, the 3rd Fleet Command ship.

The Sea and Land Ranges were the site of live action by joint forces. Efforts were orchestrated from the ITEC at Point Mugu and the IBAR at China Lake.

Another role of MC02 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. Engineers linked six U.S. Western Ranges—Army, Navy, and Air Force—into a single network. Run from the 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 USJFCOM's Joint National Training Capabilities (JNTC) network, which established a global capability for distributed joint training and experimentation. Point Mugu's OpCenter hosts the JNTC Regional Center.

The conclusions of MC02 and FBE-Juliet provided the USJFCOM with valuable information to analyze and discuss for use in future joint operations. [54]

Training for 3rd Fleet

At the Land Ranges, Fleet air units conduct bombing exercises 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 weapon systems at San Nicolas Island, Point Mugu, and the Land Ranges. In these time-critical strike operations, highly realistic target shapes are moved by NAWCWD personnel to various locations, often camouflaged. Finally, the restricted airspaces above the Land and Sea Ranges are used by the Fleet for no-fly zone exercises. NAWCWD has supported the 3rd Fleet for nearly 30 years. [54]

Common Munitions Built-in-Test (BIT)/ Reprogramming Equipment (CMBRE) Training

Smart training for a smart weapon was the goal of the JSOW Project Office when that organization invited Mobile Ordnance Training Team (MOTT) members from the Pacific and Atlantic Fleets for a visit. At China Lake, MOTT members received 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 hands-on training with the CMBRE package and a JSOW to simulate how they work in the Fleet. Projects have provided two CMBRE sets each to seven Navy carriers and two each to three Marine Corps Air Stations. The CMBRE is completely ruggedized for shipboard use and will initiate the munition's BIT component of the JSOW. The CMBRE will also upload the OFP or mission 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 approximately 3 hours, the five MOTT personnel 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]

Combat Environment Simulation (CES) Systems

CES systems simulate threat systems, thereby allowing developers to test EW capabilities, as well as provide training support to pilots. Numerous CES systems are scattered throughout training ranges to simulate SAM sites. During training exercises, pilots fly into the range simulating enemy territory, and the CES systems "lock" onto the aircrafts, at which time the pilots must react. These systems provide invaluable training to prepare the pilots for hostile environments.

During 2006, NAWCWD enhanced the training capabilities at the East Coast Training Complex, NAS Fallon, Nevada, and at Yuma, Arizona. In addition, the Tactical Air Range Integration Facility provided real-time instrumentation for live training exercises at Navy, Air Force, and Marine Corps ranges. [172]

Environmental Simulation Facilities

Environmental simulation facilities were essential to NAWCWD in the 1960s. The most common variables simulated were temperature, altitude, acceleration, vibration, salt fog, humidity, and shock. Environmental chambers, for example, 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 also be simulated, and accelerations up to 1,000 *g* 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; the entire fighter aircraft could be subjected to these elements while ordnance personnel loaded the weapons using the actual ground support equipment. [50]

Integrated Battlespace Arena (IBAR)

The IBAR is a world-class facility at China Lake comprised of nine laboratories and facilities that provide multifaceted and flexible battlespace environments created for and devoted to the Warfighter. The IBAR is capable of creating virtual environments for analyzing, testing, and evaluating interactions among warfighters, weapons, platforms, and environments.

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-optic, Ethernet, and microwave telecommunication capabilities. This complex also houses the Navy's first cockpit simulation of its kind—the Virtual Prototyping Facility (VPF). The VPF was the Navy's first cockpit simulation to include communications to and from the simulated aircraft and the weapons.

The IBAR has been instrumental in assisting various missile systems developed at China Lake. For example, during a SLAM-ER moving-target test, the IBAR simulated a Joint Surveillance Target Attack Radar System platform and

tracked a moving target (remotely controlled semitruck pulling a Scud missile). The truck's positional information was data linked via Link-16 to the F/A-18 controlling the SLAM-ER. The test was a complete success.

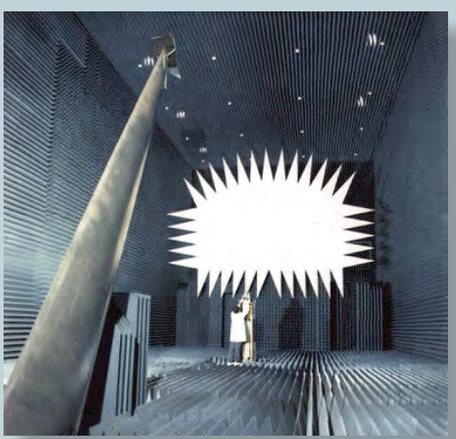
Collectively, IBAR scientists have more than 72 patents to their credit, and they are frequent contributors of papers and journal articles that explore cutting-edge issues and techniques in M&S. [116]

Missile Engagement Simulation Arena (MESA)

The MESA facility at NAWCWD China Lake provides many unique M&S capabilities. For example, missile fuzes can be tested in a secure, controlled environment. Aircraft can be suspended by wires, and full-intercept engagement conditions can then be simulated and tested, independent of weather or other environmental conditions. Hundreds of runs can be made each day in a controllable and repeatable fashion. MESA's flexibility in target positioning permits large-scale variations in target and sensor geometry, which, in most cases, can be accomplished in less than 1 minute. [203]

Point Mugu Simulation Laboratories

The Point Mugu simulation laboratories provide analog and digital simulations of major system components with HWIL to evaluate system performance in hostile electronic countermeasure environments using actual components and computer-simulated in-flight dynamics. Anechoic chambers provide vulnerability and survivability evaluation in the areas of signature and electromagnetic compatibility. The bistatic anechoic chamber (BAC) is used for radar signature for various threats, threat weapon systems, and threat simulations. The Battlespace Management Interoperability Center conducts over-the-horizon targeting, command and control, and strike mission/scenario planning with operational units in a T&E environment.



Throughout Operation Iraqi Freedom, the RRL at Point Mugu operated indoor anechoic chambers and provided unique testing capabilities in RCS measurements, analysis, and control to a wide range of DoD customers. The laboratory's BAC and large anechoic chamber have been the testing ground for numerous national defense programs. The RRL also improved Maverick's instrumentation radar in the BAC. The new radar is designed for higher phase stability, thus

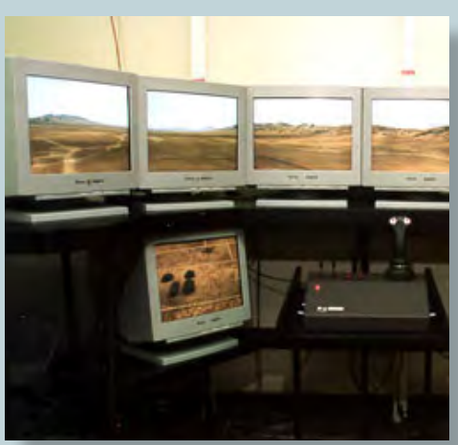
allowing lower background level for testing today's more-challenging test articles. RRL has conducted more than 115 successful test events. [172]

Tomahawk In-Flight Missile Simulator (TIMS) Pod

The TIMS Pod allowed the Tactical Tomahawk Program to fly a mission profile similar to that of the Tomahawk cruise missile and simulate the missile's in-flight environment. The challenge, however, was how to best go from laboratory testing to an actual missile flight test. NAWCWD's solution was to use a captive-carry avionics pod that employs Tactical Tomahawk guidance and new equipment flown under the wing of an A-3 Skywarrior or an F/A-18 Hornet. Therein, no hardware or software modifications were made to the aircraft.

The NAWCWD team developed two TIMS Pods with different testing configurations. The TIMS Pod allowed a full range of dynamic testing to be completed before these upgrades or new systems were incorporated into the actual missile. The TIMS Pod also reduced risk and resulted in significant cost savings over the traditional methods the Tomahawk Program used to introduce updates to the missile. After integration of the TIMS Pod onto the F/A-18, the pod's performance exceeded expectations. [54]

TOPSCENE®



TOPSCENE® is a computerized mission rehearsal system that provides mission planners, aircrew, and ground crews the ability to plan and rehearse a given mission on a three-dimensional database prior to manning their aircraft or beginning troop movements. With TOPSCENE®, the user can change environmental factors within the scene, display the HUD, attach a joystick controller, incorporate the Joint Mission Planning System (JMPS) as a moving map display, display a terrain grid, provide a playback function, display three-dimensional models (aircraft, buildings, road signs, etc.), record rehearsals in .avi (movie) and .jpg (picture) formats, establish two-point mensuration, and share scenes over local area network connections. TOPSCENE® was the first of its kind and provides a multitude of by-products, ranging from scene-generation engines and a reconfigurable trainer to full-up weapon system trainers and a standardized multi-force database for use in many different imagery display tools.

Point Mugu is the sole logistics and support activity for TOPSCENE®. This responsibility includes research and development logistics, testing, documentation, and installation. TOPSCENE® is

currently used by all four services and is deployed aboard all naval aircraft carriers and a few amphibious ships, as well as aboard most major air stations and forward-deployed troops to Iraq and Afghanistan.

The TOPSCENE® system started as a 1,400-pound multi-rack UNIX-driven system but evolved into a simple software module that can be a stand-alone system, be integrated with the JMPS, and function on a standard graphics laptop computer. The program has directly supported the War on Terror, Operation Enduring Freedom, Operation Iraqi Freedom, and Operation Desert Storm. TOPSCENE® has also supported other special events, including providing homeport security planning and supporting the 1996 Summer Olympic Games in Atlanta. [185] [225]

Virtual Missile Range (VMR)

The VMR is a simulator at Point Mugu 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. Onboard USS *Kinkaid*, a Missile All-Up-Round Simulator unit installed in the NATO SeaSparrow launcher cell performed as an actual missile. The ship calculated prelaunch conditions using the Missile All-Up-Round Simulator unit and the NATO SeaSparrow system. The signals from the NATO SeaSparrow system were encrypted and transmitted via a wireless data link to the HWIL Facility at Point Mugu. The actual missile hardware mounted on a Carco flight-simulator table then "flew" the mission. The results—whether a hit or a miss—were instantly relayed back to the ship. Observers in the Sea Range ITEC watched the "flights" through the VMR's Real-Time Viewer Program. [54]

The VMR has been fully integrated into Sea Range operations, and electronic countermeasure simulations have been installed in attempts to fool the defensive systems. With this latest upgrade, the STG now has the capability of projecting numerous different electronic countermeasure techniques with any of its incoming synthetic threats. During shake-down tests of the VMR upgrade, numerous presentations were made to the weapon system.

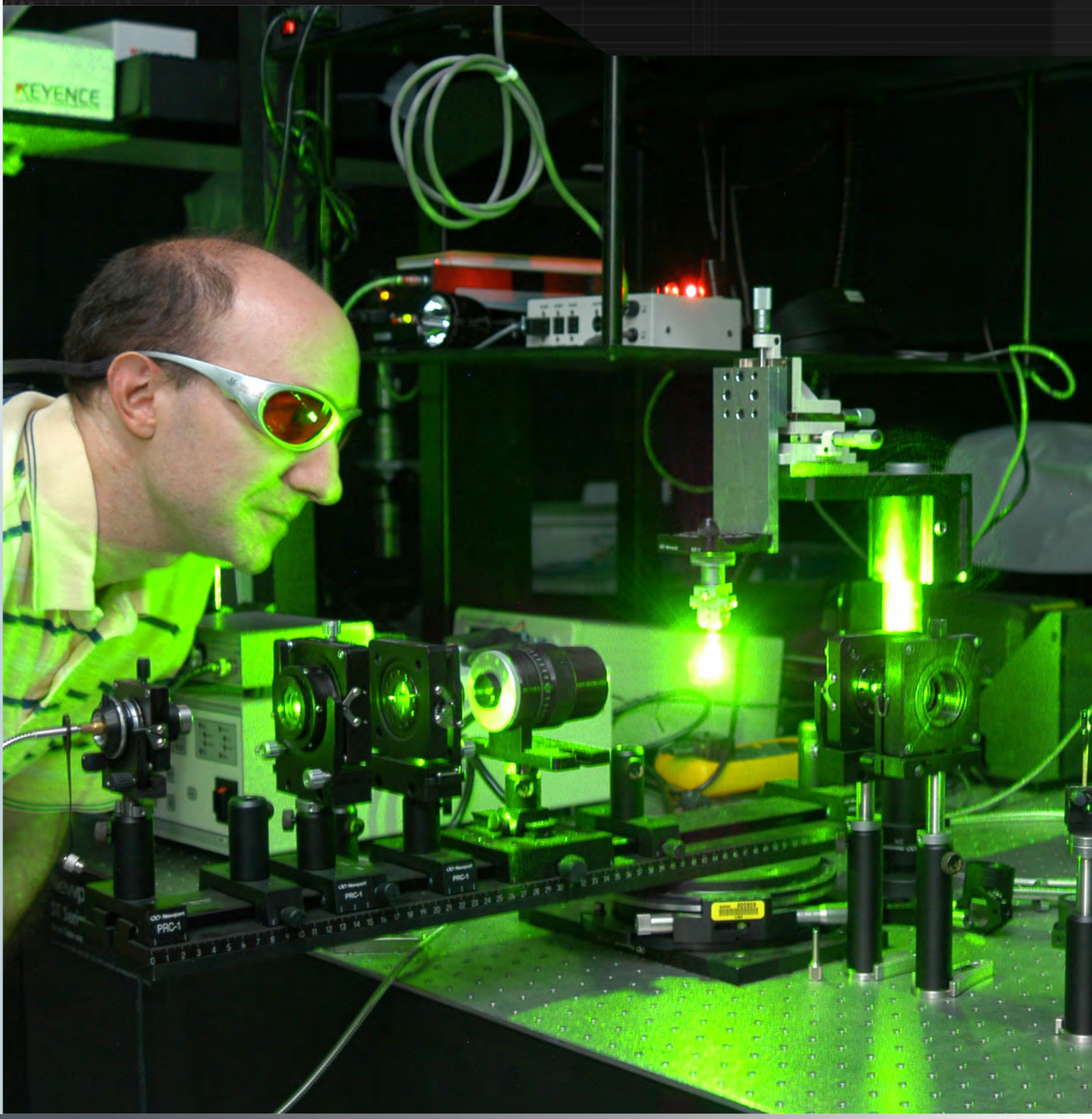
The VMR is being upgraded with multi-axis threats, maneuvering threats, vertical launchers, and other platforms' missile systems. [226]

Weapons and Tactics Analysis Center (WEPTAC)

From 1978 to 1997, China Lake maintained WEPTAC, an interactive warfare simulation facility. The early concept was to see if an interactive simulation facility could be based on minicomputers and developed at low cost. WEPTAC allowed users to make battle decisions in a limited-information environment, as well as when 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. Typical projects included air-to-air and air-to-ship attack tactics development, force projection/close-air support tactics study, and conceptual weapons/sensors/platform study, as well as evaluation of tactics developed by pilots at NSAWC, NAS Fallon, Nevada, and the F/A-18 at NAWCWD.

The system grew from a small prototype to an advanced system that was capable of modeling up to 1,200 aircraft or ship units, each one capable of carrying up to 30 weapons or sensors, including electronic countermeasures. 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 and Engineering



Research and Engineering

Throughout its history of excellence, NAWCWD has maintained a strong research, science, and technology base. These efforts are at the forefront of new weapons and systems development that give the Warfighter a decisive advantage. Extensive research is conducted annually in a wide range of topics, including combustion sciences, firefighting, IM, energetic materials, ordnance and propulsion, and laser and optical components. NAWCWD often partners with other national and international government research agencies, such as the Defense Advanced Research Projects Agency (DARPA), ONR, NASA, and NATO. NAWCWD also often partners with private industry in joint research projects.

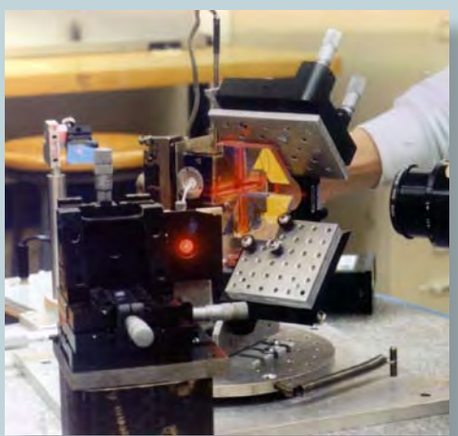
While NAWCWD has produced countless advances in research, science, and technology, this chapter discusses only a handful of the hundreds, if not thousands, of technological advances contributed by NAWCWD. A comprehensive list of all advances in technology would require volumes of documents, but the advances discussed in this section illustrate the diverse array of technological areas related to NAWCWD involvement.

Biology

Aircrew Physiological Studies

Point Mugu developed 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 bodily functions. This device transitioned to the In-Flight Physiologic Data Acquisition System (IFPDAS), which is used at Point Mugu to monitor aircrew flying the A-4, F-4, and F-14 aircraft. By the late 1970s, Point Mugu engineers made further advancements to the IFPDAS III. This knowledge was used to develop specifications for future life-support systems. [50]

Biomimetics



In 2008, as part of a new biomimetic technology initiative, NAWCWD China Lake released a study conducted in association with the University of Wyoming on the eyes of flies and other insects. The common fly has an amazing ability to find moving targets in cluttered backgrounds, as well as land on moving "platforms." Researchers wanted to know how flies accomplish these tasks effortlessly and then possibly apply this research to improve imaging sensors and signal processing. From this research, a fiber-optic sensor was developed. Coupled with analog preprocessing hardware, this device has the potential to extract edge information quickly and in parallel. The sensor consisted of

a 1-millimeter-diameter ball lens that focuses light onto an array of photodetectors, where the field of view overlaps by about 70%. In experiments, the sensor could locate a 1-millimeter-wide string as the string moved across the field of view at distances up to 200 millimeters from the lens, with minimal error. This quality of high-resolution systems could also have future applications in various medical, commercial, industrial, and defense areas, including robotics. [233]

Chemistry

Advanced Oxidation Technologies (AOTs)

AOTs refer to a group of chemical and physical processes that can 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, thus producing only carbon dioxide and water. A photocatalytic oxidation system was originally tested at the Naval Air Depot Jacksonville to evaluate the potential for treating high-strength organic wastewater by using 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 focuses on improved semiconductor catalyst applications. Semiconductor materials have been synthesized, characterized, and tested and are validated against industry standard materials. Testing is also 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]

Chemical/Biological Agent Defeat Program

China Lake is currently studying ways to defeat chemical and biological weapons. In association with the Defense Threat Reduction Agency (DTRA), these studies focus on three different energetic materials—enhanced thermites, solid interhalogenate salts, and difluoramine explosives. The goal is to create explosive fills that, upon detonation, generate species that kill biological weapons and break down chemical weapons. In tests against simulated biological weapons, spores were killed after only 20 minutes of exposure. [172]

Clean-Power Generator

Scientists at China Lake are researching new ways to bring clean power to off-grid targets, radars, repeaters, and radios on the test ranges, as well as, on a larger scope, helping to 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 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 then 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 by-products, and energy stored through this process can provide power without sunshine for 3 to 4 days. The hydrogen generator provides 950 watts, which is enough electricity to power two hand-held hair dryers, but, after further testing, the system could be used throughout China Lake in 500-watt blocks. Actual implementation of the fuel cells on the ranges is several years away. The system could eventually have much wider usage throughout the Fleet and possibly for civilians. [102]

Corrosion Prevention

NAWCWD has sought to replace the toxic heavy metals cadmium and hexavalent chromium with environmentally friendly electro-active polymers in coating systems on aluminum and high-strength steel parts for marine aircraft. NAWCWD researchers have performed pilot-scale synthesis, coated test panels, and tested coating system performance as part of joint efforts with the Army, Navy, Air Force, and multiple universities to see if the new materials can replace the toxic ingredients in aircraft coating formulations. These materials are compatible with environmentally friendly coating processes (such as volatile-organic-compound-exempt spraying and electrostatic deposition) that are also well suited to affordable mass production. Field testing of coating systems containing some of the new materials on noncritical equipment at NAVAIR, Army, Air Force, and NASA facilities is currently being evaluated. [197]

Full-Spectrum Ballistic Eye Protection

In 2009, NAWCWD demonstrated a new material that improved contrast ratio and switching speeds in full-spectrum ballistic eye protection. The clear state allows for more than 85% light transmission, while the dark state transmits less than 20%. This material can also clear from 30 to 80% in less than 1 second and darken from 85 to 50% in 3 seconds. Only minimal power is required to darken the lens. No power is required to keep the lens dark, and it can stay dark for weeks. The current produced when the lens is cleared is proportional to the level of darkening. In that way,

the electrochromic lens acts like a rechargeable battery in which the level of charge is indicated by the level of darkening. [172] [203]

High-Temperature Composites

NAWCWD developed new breakthroughs for a new class of materials to be used in weapons and aircraft that operate in the marine environment. These new resins are capable of surviving for short periods at temperatures in excess of 700°F. For example, some can withstand the heat from a blowtorch. A major milestone was achieved in 2005, when NAWCWD researchers created the world's first carbon-fiber-reinforced composite article made from these new materials (high-purity arylethynyl-terminated polyphenylenes). In 2006-2007, Boeing Phantom Works delivered the first high-quality carbon fiber composite structural panel made from these polymers. Polyphenylene resins are inexpensive, absorb very little water, and are compatible with efficient manufacturing techniques. Until this research, though, no one had proven that this material could be fabricated into a high-quality composite structure because the effort often took years. By teaming with Boeing Phantom Works, NAWCWD researchers were able to design the polymer so that a high-quality structural composite part was produced on the first attempt. This achievement puts NAWCWD in a position to develop and produce testable structures in a span of weeks rather than years. [197]

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 systems must be versatile enough to provide the exact amount of thrust required for a specific mission with precision timing. 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 with minimal weight.

NAWCWD is developing these propulsion systems for kill vehicle divert and attitude control systems. For this application, NAWCWD developed and demonstrated nontoxic hypergolic bipropellants using concentrated hydrogen peroxide (>90% concentration) as an oxidizer and a new class of nontoxic fuels, known as nontoxic hypergolic miscible fuel. NAWCWD is also 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. As a result of these successes, industry is now collaborating with NAWCWD to transition these technologies to a number of military and commercial applications. [103]

Molecular Photonic Materials (MORPHs)

China Lake continues to participate in the DARPA MORPH Program. The program's emphasis is to build a low-voltage high-bandwidth optical modulator and sensor-protection devices. Films and devices of revolutionary new nonlinear optic (NLO) materials are prepared in laboratories at Lumera Corporation, the University of Washington, and the Georgia Institute of Technology. Scientists at China Lake, the Air Force, Army, Naval Research Laboratory, and the Laboratory

for Physical Science (University of Maryland campus) form the team for modeling, testing, and evaluating the NLO organic materials. Films in devices tested in government laboratories have achieved record-setting electrooptic coefficients.

Nanoscale Metal Powders and Reactive Composites

Metal fuels, like aluminum and magnesium, are used in many propellants, flares, countermeasures, and explosives. One area of intense research at NAWCWD is nanoscale metals and composites. Nanoscale materials are roughly one billionth of a meter in size. In the mid-1990s, NAWCWD scientists found that fine-grain (150-nanometer) metal powders developed in Russia were capable of enhancing detonation velocities in explosive and increasing propellant burning rates two- or threefold. NAWCWD developed and patented a new solution method for preparing fine-grain aluminum powders (50 to 500 nanometers). In collaboration with Los Alamos National Laboratory (LANL), NAWCWD also patented lead-free percussion primer mixes based on metastable interstitial composite technology—nanoscale composite mixtures of an ultrafine metal fuel and an oxidizer. These primer mixes could replace conventional ammunition primers that use either lead azide or lead styphnate, two toxic materials that cause neurological, gastrointestinal, reproductive, and renal damage in humans. NAWCWD's current research on the aging and prevention of aging of nanoscale metals and composites will enable the deployment of weapon systems with nanoscale energetic components. Nanoscale materials also have an enormous potential in electronics, biomedical applications, and microelectronic machines.

Navy P3 Resin

In 2009, NAWCWD successfully produced a P3 polymer with a phenylethynyl end cap (Navy P3 resin) using a controlled temperature scale-up for the first time. The batch weighed more than 1 pound and will allow composite test panels and cylinders to be manufactured for evaluation at China Lake. The resin offers significant gains in affordability, moisture resistance, and safety during fires compared to current resins.

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

Chemists at NAWCWD have developed several NLOPs that offer lower cost and higher performance in fiber-optic, avionic, and photonic applications. For example, these polymers will become part of a revolutionary new guidance capability that will allow troops to stand off at great distances and take out enemy targets with pinpoint accuracy. NAWCWD is developing new NLOPs for use in high-speed optical signal processing devices, such as electrooptic modulators, optical switches, and frequency doublers. These polymers make use of special chemical syntheses

procedures designed to attach a wide variety of molecules to polyimides without altering or harming the molecule being attached. NAWCWD developed a unique way of keeping the molecules intact during attachment. [59] [172]

The NLOP research field is growing rapidly, and new developments also have the potential for providing new devices and systems for the telecommunication and data communication industries at ten times greater bandwidth.

Optical Dome Material Work

Since the first IR-guided Sidewinder missile flew in the 1950s, NAWCWD China Lake has developed domes with improved durability to protect seekers' delicate optics. IR 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 adverse weather conditions, such as rainy Vietnam. In response, China Lake built an artificial rain field at SNORT, 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 3 decades, it became the most widely used dome material, being installed in approximately 100,000 air-to-air missiles.

In response to shortcomings regarding thermal shock, NAWCWD 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 the 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 also 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, NAWCWD China Lake is exploring new frontiers in developing window materials with nanometer-size grains that might possess increased strength and ability to form complex shapes, thereby opening up the possibility of fabricating tough composite windows. [161]

Unitary Fuze Module

In 2005, NAWCWD researchers applied for a patent for a new unitary fuze module with its own onboard sensors that monitor the environmental conditions and arm the weapon when the required conditions are met. These conditions may be at a safe separation distance from the launch platform or at a decreasing distance to the target. Personnel can easily install the self-contained

fuze module with only one bus connection to the launch platform on ordnance such as JDAM. Having onboard sensors results in more-reliable arming. This capability is especially important because unexploded ordnance is used by insurgents to create IEDs.

Very-Low-Absorption Coatings

China Lake researchers are working with the Air Force to improve window materials, coatings, substrates, and optical metrology that will improve the performance of beam and fire-control optics on the Airborne Laser. These new technologies will have direct applications for heat-seeking missiles, surveillance and tracking systems, and high-power lasers. Improved antireflection coatings will also increase standoff distances, enhance resolution and target recognition, and provide better discrimination of decoys, as well as mitigate sea-surface glint and reduce power requirements for future versions of weapon systems, including the ATFLIR pod, Standard Missile, and Sidewinder.

In addition, NAWCWD invented a new coating material called Varidex that has a refractive index that can be tailored to reduce unwanted reflection and transmission loss. NAVAIR's continued investment in state-of-the-art capital equipment, such as high-density plasma-deposition systems, has allowed NAWCWD to maintain its leadership role in optical coatings.

Computer Technology

Bomb Mission Planning Tool

NAWCWD developed a graphical user's interface (GUI) for the naval stores planning and weaponeering component of the Joint Munitions Planning System. Fleet support turned the GUI development into a stand-alone program. NAWCWD enhancements evolved from interactions with warfighters and expertise in weapons systems. NAWCWD integrated Joint Munitions Effectiveness Manual hard-target penetration tools into a Paveway Munitions Planning Tool (PMPT), thus providing a "one-stop" tool for LGB mission planning. The PMPT is a Paveway II and Paveway III LGB mission planning tool that provides users with a launch acceptability region from which to release weapons, to calculate single trajectories for time-of-flight and lasing-time analysis, and to compute penetration into hardened targets. The software runs on Windows operating systems. Version 1.0 was released to the Fleet in June 2001. The Navy and the Air Force used the PMPT successfully in Operation Enduring Freedom and Operation Iraqi Freedom for LGB mission planning. [73]

Early Computer Technology

In 1946, the world's first fully electronic computer, the Electronic Numerical Integrator and Calculator (ENIAC), began operation at the University of Pennsylvania. In 1950, China Lake was eager to adapt the new machines to its needs. Two China Lake 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 1951, when the new Reeves Electronic Analog Computer (REAC) was set up in a hallway of Michelson Laboratory. By today's standards, it was a clumsy device, requiring approximately 3,000 vacuum tubes to make it work; however, at that time, REAC was a marvel of efficiency and was used to perform early Sidewinder simulations to calculate the aerodynamic characteristics for the rocket-assisted torpedo needed under various ship-launching conditions. [49]

In the early 1950s, Point Mugu had one of the first large digital computers ever built, the Raytheon Digital Automatic Computer (RAYDAC), 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. [50]

The Technical Library at China Lake also developed a computer system in the 1950s that could search a database by subject. The IBM 701, the first mass-produced computer and defense calculator, is credited with conducting "the first subject search ever made by a digital computer" in 1954. Only 19 IBM 701s were installed nationwide, and the eighth unit built was installed at China Lake. Simplifying 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 on the West Coast. Even today, most bibliographic searching still relies on coordinate indexes. In the 1960s, more-sophisticated searching programs were developed by using the IBM 7094 with a program called the Library Information Search and Retrieval Data System. These programs helped to reduce the cost of computer time. [164]

Level Set Geo-Registration Image Enhancement

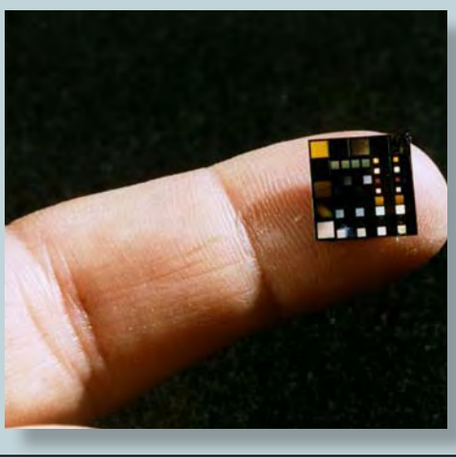
Using a mathematical theory known as level sets (best analogy is a topographic contour map), China Lake researchers, in association with Cognitech, developed a tool that automatically registers video or still frames from tactical sensors to a Digital Point Positioning Database or other controlled reference image base. Using level sets and registration, Navy personnel can perform a variety of image enhancements. Level set geo-registration allows for frame fusion and integration, thereby clearing up distortion in the video frames.

Directed Energy Weapons (DEWs)

DEWs are large concentrated doses of energy (i.e., photons or particles traveling at or near the speed of light) directed toward targets to destroy them. Because a DEW beam can travel great distances almost instantly, the target's chances of evading the beam are miniscule. DEWs provide the U.S. military a technology that totally changes how warfare will be conducted in the future, thus giving the United States a decisive advantage over its enemies.

China Lake is currently conducting research and development of high-energy laser (HEL) technology, including using fiber lasers, laser architecture support beam control, microwave radiation emitters, electromagnetic rail guns, particle beam accelerators, and diode pumps. Laser weapon projects tested at China Lake included the Laser Avenger, which is a High-Mobility Multipurpose Wheeled Vehicle (HMMWV)-mounted directed energy air defense system. During a 2009 test, the Laser Avenger shot down six drone aircraft over the Land Ranges. In 2010, a laser weapon system successfully tracked, engaged, and destroyed a drone in flight during a test at San Nicholas Island on the Sea Range. This test was significant and illustrated the potential lasers can provide to the U.S. military. Typically, a laser loses effectiveness as it moves through a moist, salty sea air, but, as the DEW demonstrated, it did not lose power and was accurate. The Navy expects to one day use laser weapons to intercept antiship missiles and other threats, including smaller ships (i.e., pirate skiffs).

China Lake is also involved in other areas of science and technology for tactical aviation HEL, including atmospheric propagation of laser beams, laser source developments in fiber lasers, laser effects, and beam control and aimpoint maintenance. [172] [219] [227]



Electronics

Microelectromechanical Systems (MEMS)

Miniaturization technologies, such as MEMS and nanotechnology, are the future, and NAWCWD continues to develop multi-point initiation for an electromagnetically actuated MEMS device. High-speed digital video cameras

were placed to capture the timing between the detonations. Post-shot inspection indicated that all micro-explosives detonated, as evidenced by dents and hole expansion. Extensive testing with MEMS contributes to the production of micromachines, micro-integrated circuits, and microoptics that will be used in the defense, security, and aerospace sections. [172]

Super-Capacitor Technology

NAWCWD researchers work with private industry and academia to develop super-capacitors that will demonstrate 80% charge storage retention after 100,000 cycles at 75% depth of discharge. This project will significantly reduce the size and weight requirements for power supplies for air weaponry, UAVs, and portable electronic devices for weapons, communications, computing, surveillance, and sensing. In addition, materials used will be safer and more environmentally friendly. NAWCWD has developed a new type of super-capacitor that can deliver 3.5 volts from a single cell, thus making these devices competitive with lithium ion batteries.

Energetics

CL-20

In 1987, researchers at NAWCWD China Lake invented CL-20, a breakthrough in energetic materials, a compound with a higher energy density and lower sensitivity than those of previous materials. 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 also has important applications in the commercial world. A CRADA was established with Thiokol Propulsion to perfect the material for scale-up to commercial production and availability for military and commercial applications. [192] [219]

Improved Combustion in Thermobaric Explosive Formulations

In 2005, three new patents were issued to NAWCWD researchers for creating thermobaric explosives with improved combustion efficiency. Thermobaric explosives work by first expelling a cloud of explosive mist using a small charge and then igniting it with a second charge. While effective in open spaces, these types of bombs have proved ineffective in confined poor-oxygen environment areas, such as in tunnels. The new explosive components have a 50 to 100% higher blast energy and will help to eliminate these problems. [172]

Insensitive Munitions Technology Transition Program (IMTTP) Warhead Demonstration

In 2004-2005, IMTTP efforts greatly improved the IM performance of a 5-inch-diameter warhead when compared with the existing Sidewinder warhead. This capability was demonstrated by utilizing both a directional-based initiation design and the conventional end-initiated design currently used. Working with the Joint Navy/Air Force IM Bomb Program, NAWCWD designed new annular bomb fills with shock-attenuating liners to mitigate sympathetic detonation in general purpose bombs. NAWCWD also evaluated high-temperature and metal matrix composite case materials to further enhance IM stability. For example, NAWCWD designed and tested the first iteration of a pumice barrier for Tactical Tomahawk that could effectively double the number of all-up rounds that are safely shipped in the logistic configuration. [172]

Integrated High Payoff Rocket Propulsion Technology (IHPRPT) Program

Meeting the demand for future Navy missiles requires continuous technology development. The IHPRPT Program, started in 1994, is an integrated tri-service/NASA/industry effort to develop and demonstrate innovative, revolutionary technologies that will double rocket propulsion capabilities, including boost, space, and tactical. NAWCWD handles 80% of the tactical IHPRPT Program, leads the tactical demonstrator program, and bears overall responsibility for propellants and control systems. Significant progress has been made toward achieving the goals of increased delivered energy and mass fraction because of the development of propellants with higher-energy ingredients (CL-20 and ammonium dinitramide). Because of improved propellants, composite motor cases, low-eroding nozzles, and innovative thrust vector control systems, higher operating pressures are now possible. [105]

In 2005 and 2006, NAWCWD completed payoff studies involving the AIM-9X, AMRAAM, and RAM, and results showed significant improvements in increasing propellant energy and motor volumetric loading, decreasing component weight and volume, and increasing component efficiency, without sacrificing safety or increasing cost. [172]

Joint Technical Coordinating Group on Aircraft Survivability (JTCG/AS)

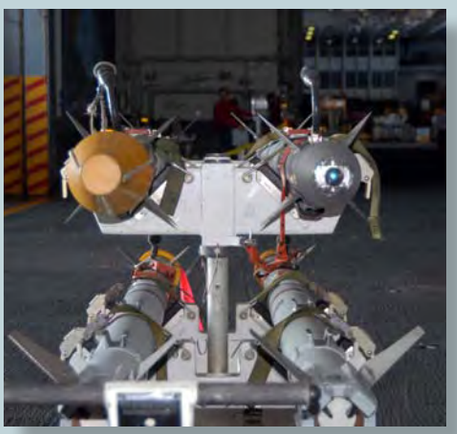
Fire is a leading contributor to attrition of aircraft in combat. Active fire-suppression systems, however, can often be complex, costly, and heavy. Various passive fire-protection technologies exist that are low cost and low weight. For example, the simple passive extinguisher involves a reactive agent placed or installed directly within the aircraft compartment. Fire activates the

agent, which rapidly fills the compartment and extinguishes the fire. In addition, upon ballistic impact, reactive powder panels will break open and release the encased fire suppressant powder. The JTCG/AS project at China Lake is investigating the use of an energetic material to enhance powder release from such panels. For example, ionomer fuel containment technology could be used 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]

NAVSEA/NAVAIR Navy Energetics Program

The power of energetic materials is a critical Navy technology, ranging from a 5-milligram low-energy initiator to an 81,000-pound rocket motor. 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's Energetics Integrated Product Team (EIPT) are forging a unified NAVSEA/NAVAIR energetics program that represents all four of the Navy's energetics laboratories: Crane, Indiana; Dahlgren, Virginia; the Indian Head Division of the Naval Surface Warfare Center, Maryland; and NAWCWD at China Lake and Point Mugu. The NELB will "preserve the Navy's competency in energetics, foster collaboration among warfare centers, and speak for the Navy energetics [community] with a single voice." The EIPT, on the other hand, is tasked with "formulating clear, realizable vision for Navy's energetics future; defining a coordinated Navy energetics strategy; developing an energetics technology and requirements roadmap; and actively pursuing collaborative projects between the system commands." [97]

Reduced-Smoke Propellant



At the end of World War II, solid rocket motors were made from the same smokeless double-base propellant (i.e., nitroglycerine and nitrocellulose) used in guns. More-modern rocket motors, however, use propellants composed of rubber binders filled with powdered ammonium perchlorate and solids like powdered aluminum. This composition performs better than previous propellants and can be cast into motors of any size and shape but produces a white smoke that, in certain weapon systems, is extremely disadvantageous. In response to the needs of the Sidewinder and the HARM teams, during the 1960s, China Lake engineers developed a composite propellant without the aluminum powder. This became known as a reduced-smoke propellant. Removing the aluminum caused only a slight reduction in performance but did introduce the problem of combustion instability. China Lake soon solved this problem by developing reduced-smoke motors for Sidewinder and HARM in the 1980s. [159]

Roseville–Benson Investigations

In 1973, explosions rocked two different trains carrying Air Force bombs filled with Navy-developed explosives. The incidents, one at Roseville, California, and the other at Benson, Arizona, shook public confidence in the safety of transporting military ordnance and resulted in a lawsuit 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 the trains' faulty brake shoes that set fire to the wooden boxcars carrying the bombs. Over a period of 7 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]

High-Speed Weapons (HSWs)

High-speed supersonic and hypersonic weapons can provide dramatic improvements in platform and weapons survivability, in the ability to engage time-critical targets, and in the penetration of hardened and deeply buried targets. NAWCWD's strategic objective is to position itself as the leader in HSW development, thus giving the United States a definite decisive advantage.

NAWCWD has conducted extensive work in the technologies required to make such weapons a reality, including efforts in advanced airbreathing propulsion systems (i.e., ramjet), blended body airframes, high-temperature materials, and ordnance package concepts. Programs such as RATTLRS are under way to demonstrate these technologies in flight testing. [172] [219]

Increased Capabilities Against Moving and Stationary Targets

NAWCWD is currently developing two systems to increase the Navy's capability to engage moving and stationary surface targets in all weather conditions. The first system is the Direct Attack Seeker Head (DASH), a low-cost dual-mode (imaging IR/millimeter wave) seeker for attacking moving and stationary surface targets in adverse weather conditions. DASH's goal is to provide that much needed capability to the Tactical Tomahawk, but the modular seeker design will allow integration into a variety of weapons by using adapter kits.

To date, the commercial off-the-shelf imaging IR sensor was selected and procured, the radar sensor design was completed, all subcomponents were fabricated, and the core processor design

was completed and moved to printed circuit layout and fabrication. Integration onto the Tactical Tomahawk is tentatively planned for 2012.

The second system is the multimode sensor seeker, which utilizes visible, IR, and laser radar sensors in correlation with advanced automatic target recognition algorithms to increase target identification in all-weather maritime environments and reduce false alarm rates and operator workload. The sensor hierarchy will also provide increased standoff range. This system is intended for the MQ-8 Fire Scout but may also be placed into future weapon systems.

In 2008, the sensor subsystem contract was awarded, and the project completed a systems requirements review and began preliminary design work. In 2009, the preliminary design review was completed, and a preliminary design was developed. [172] [219]

Missile Airframe Technology

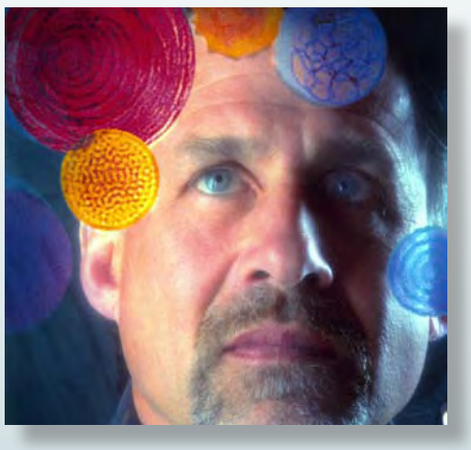
NAWCWD missile airframe technology efforts provide affordable airframe structures, stable weapon flight, increased maneuverability, safe separation from launch platforms, reduced drag, improved aero-prediction and defense penetration techniques, and high-temperature airframes.

NAWCWD 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 time, there was no accepted method to qualify manufacturers. NAWCWD is developing the advanced high-performance motor cases needed to satisfy IM requirements and the lightweight high-temperature structures required for high-performance hypersonic weapon 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. This technology was transitioned to the RAM Risk Reduction and Common Modular Missile Programs. NAWCWD 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, NAWCWD uses the Integrated Hypersonic Aeromechanics Tool for design trade studies and optimization. [99]

Physics

Nanoplasmonics and Metamaterials



The need for miniaturization of optoelectronic components is critical for reducing the footprint and weight of future weapons systems. Currently, most optical devices are built at the scale much larger than the wavelength due to the limitation of wave diffraction that prohibits light transmission in the sub-wavelength scale. The latest developments in nanoplasmonics and metamaterials offer the potential to overcome this diffraction limit, thus enabling devices to be built in the sub-wavelength scale. Another newly discovered application of these materials is a novel physical effect of the nonlinear properties of metamaterials. Nonlinear metamaterials can shield objects from high-power laser beams. It has been observed that the shielding strength increases with increasing laser power.

NAWCWD is currently studying mathematical analysis, electromagnetic modeling, and fabrication of metamaterials. Investigations are also under way in areas such as metamaterial antennas for UAVs, metamaterial waveguides and transmission lines that can operate in the sub-wavelength region, optical scattering from metallic rods at grazing incidence resulting in Sommerfeld resonances, fabrication of novel dielectric/metal stacks for optical/IR metamaterials, and state-of-the-art chemical thin-film fabrication techniques. This work is supported by ONR and NAVAIR Independent Applied Research and In-House Laboratory Independent Research Programs, as well as by China Lake discretionary funding from the RF and electrooptic initiatives. [172]

Radiant Virgo and the Moving Target Demonstration

Under the Radiant Virgo project, researchers developed an application that provides automated geo-registration of tactical UAS video obtained from electrooptic and IR sensors. With the use of a Digital Point Positioning Database to help derive precise coordinates, PGMs can then engage relocatable, nonmoving ground targets in nearly real time. Virgo was also adapted to utilize other nongovernmental resources, including WorldView1.

The technology was first demonstrated during Empire Challenge 2009 by using a live coalition network feed from ScanEagle. The technology was subsequently demonstrated to Commander, Space and Naval Warfare Systems Command, and Commander Operational Test and Evaluation Force with linkage between NAWCWD and the Space and Naval Warfare Systems Center in San Diego.

The moving target demonstration builds on the geo-registration capabilities of Radiant Virgo by incorporating a moving tracker. This modification will provide PGMs with moving target track capability for passive moving target tracking and precision engagement on the ground. The goal

is to automatically track objects of interest and provide automatic geo-rectified updates at 1/2- to 1/5-second intervals. [172]

Technology Transfers

Technical transfer refers to the process of transferring a specific technology developed by the government and made available to industry. While NAWCWD's primary focus is on research and development of weapons for the Navy, many discoveries during research can be beneficial to industry and have nonmilitary uses, as described earlier.

The Federal Laboratory Consortium (FLC), the primary national federal technology transfer group, was originally established by China Lake in 1971 as the DoD Technology Laboratory Consortium for Technology Transfer and grew from 11 original laboratories in 1971 to 200 laboratories in 1975 under China Lake's leadership. Today, the FLC consists of more than 250 federal laboratories and centers and their parent departments and agencies. 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.

NAWCWD 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 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 NAWCWD contributions resulted from investigations into wind, solar, and geothermal energy; solid waste conversion to clean-burning fuel; aircraft survivability; and an explosive device used to clear fire lines for the Forest Service. [41]

It would require volumes of documents to describe all the research and technology that NAWCWD has transferred to industry. The following subsections, though, highlight many of these achievements.

Actuated Cable Cutters

In the early 1950s, China Lake 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 was transferred to private industry, and, today, several companies have developed advanced cartridge-actuated cutting tools that are used nationwide, as well as by many countries throughout the world for police, sheriffs, special weapons and tactics (SWAT) teams, and fire departments to cut security bars, chains, and locks. [8]

These tools are also highly effective "jaws of life" for cutting through steering wheels and break pedals. The electric power line industry across the United States and in some foreign countries is also 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 City bombing, cutters were used by the fire department to rescue trapped individuals.

Calcification-Prevention Tablets

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 hydroblasting, which is expensive and time-consuming. NAWCWD China Lake scientists developed inexpensive, environmentally friendly water-soluble polymers that are placed into urinals in tablet form and release citric acid to bind the calcium in the flush water. Today, virtually every ship in the U.S. Navy carries and uses this product. This technology is also being used by industry in countless commercial vessels and facilities worldwide. [203]

Chemiluminescent Light Stick

NAWCWD China Lake developed the chemiluminescent light stick technology between 1962 and 1986 for 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 it was licensed commercially. Commercial uses include novelty items and safety illumination sticks for emergency kits and commercial fishing lures, as well as brightly glowing novelty safety necklaces. This technology also received the 1993 FLC Award for Technology Transfer Excellence. [203]

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 the DoD used this compound extensively. CFCs, however, also fell into the category of ozone-depleting compounds. Under President George H. W. Bush, the United States decided to phase out CFCs by 1995. NAWCWD China Lake evaluated commercially available non-ozone-depleting products for cleaning electronic assemblies and helped to 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. It, unfortunately, was also being phased out. In response, NAWCWD developed gas generators ("pyrotechnic extinguishers") that produced large quantities of inert gases to smother fires. The first patent for this technology was issued in 1986. [148]

Continuous Emissions Monitor (CEM)

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 NAWCWD China Lake and Thermo Jarrell Ash Corporation was formed, and the system 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* 100 Awards. 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 of the TraceAIR™ system were also awarded a 1998 Award for Excellence in Technology Transfer by the FLC. [130]

Diamondoids

In 2004, NAWCWD negotiated a CRADA with Chevron to jointly develop new products based on "diamondoids," which are nano-diamond fragments that are very rigid and stable. ChevronTexaco recovers diamondoids from natural gas wells. NAWCWD is exploring potential uses as building blocks for optical and structural components of future weapon systems. Decades ago, similar compounds were investigated for airbreathing rocket fuel at China Lake, but new purification methods are making a wide variety of new structures available for other applications. [172]

Dual Polarized Broadband Tapered Slot Antenna

NAWCWD researchers invented a low-cost, lightweight dual polarized broadband tapered slot antenna that can be used for multiple applications and is very cheap to manufacture (e.g., $200 versus the $5,000 charged by contractors). The first and second radiating antennas are colocated and positioned to be perpendicular to one another. Each antenna includes a relatively thin dielectric substrate and a radiating metallic antenna element mounted on the upper surface. These new antennas allow for linear, elliptical, and circular polarization. [172]

Electrical Initiation System

Electrically ignitable primers have been previously used in military applications for high-speed firing of various-sized-caliber ordnance; in blasting for mining operations; for automotive crash bag initiation and inflation; and for seismic guns, kiln guns, rocket motors, and pyrotechnic displays. Many of these primers, however, are not suitable for small arms such as rifles, pistols, and shotguns. Typically, electrically ignitable primers initiated by exploding bridgewires or hot wires in combination with a semiconductive mixture, pyrotechnic mix, or conductive mix suffer from relatively long ignition times. This new electrical initiation technique relies substantially on vaporizing a thin metallic film or strip and rapidly igniting a lead-free explosive composition. The patent on this technology was awarded in 2005. [172]

Environmentally Friendly Mixture of Trinitrotoluene (TNT)

NAWCWD researchers were issued a patent in 2005 for making an environmentally friendly explosive mixture of TNT by using a cyclodehydrative condensation mechanism for melting the high explosive. This method does not produce unwanted highly toxic nitration isomers that must be discarded, a very expensive process. The new materials generated can be safely reused. [172]

Exploding Foil Initiator (EFI) Based Squib Arm-and-Fire Device (AFD)

During the Bosnian conflict, China Lake developed the low-energy exploding foil initiator (LEEFI), which is used in-line with main charge explosives to safely initiate warheads. The LEEFI employs microelectronics technologies that required only half as much energy as conventional initiators, and production was two-thirds less labor intensive. In 2004, EFI technology advanced and has significantly reduced the cost and weight of rocket motor safety devices. Other applications include use in thermal batteries, non-detonating self-destruct mechanisms, and pyrotechnic ignition devices.

Explosive Forming and Welding

During the 1960s, NAWCWD China Lake invented explosive forming and explosive welding, two exotic techniques that revolutionized metal fabrication. In the course of investigating terminal ballistics, shaped charges, and metal-explosive systems, China Lake scientists 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, thus 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 (because die alignment is avoided) and have high accuracy. In addition, they are useful for forming metal sheet and tubular parts; complex shapes such as double curved surfaces; and large, thick parts. Explosive welding also bonds two surfaces in a solid state by creating a jet of metal in front of the detonation front. Originally employed to clad large areas of one metal with another, the technique is now used to produce corrosion-resistant pressure vessels, electrical bus bars, transition joints for shipbuilding, and heat exchangers for nuclear installations. Today, the techniques pioneered by NAWCWD China Lake are widely used in the aerospace and aircraft industries, as well as in the production of automotive components. [40]

Geophysical Warfare, “Rainmaking”

During the Vietnam conflict, the United States military needed a way to interdict enemy traffic on the Ho Chi Minh Trail. NAWCWD China Lake developed weather manipulation technology to “seed” specific clouds to enhance rainfall, thereby significantly deterring enemy activity on the trail. NAWCWD personnel participated in Operation Popeye, a top secret project (now

declassified) to train B-52 pilots to use C-130s to seed certain clouds. This project was highly successful, and the Ho Chi Minh Trail was washed out, thus making it impossible for the enemy to move to their destinations. This project was the first time the military manipulated the weather as a weapon. This highly successful technology is used today by industry in hurricane abatement, fog control, and drought relief. [167] [228]

Geothermal Energy

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 alternative energy program, thereby allowing the Navy to become more independent of foreign fuels. A contract was awarded to California Energy Company, Inc., in 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 milliwatts is from Navy land and 81 milliwatts is from Bureau of Land Management leases.

The Coso Geothermal Project is a world-class resource, ranking among the top 10 in total power output. NAWCWD receives a reduction in its electricity bill every month, an agreement that has been in place since power was first generated in 1987. Total savings to NAWCWD since that time exceed $36 million, and 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 Geothermal Project will produce with its four geothermal power plants over its 30-year lifetime. [141]

The military set a goal that 25% of its energy should come from renewable sources by 2025, and NAWCWD China Lake was assigned the lead role for all Navy geothermal efforts, even those not geographically limited to China Lake. As environmental concerns continue to shift toward "greener" power sources worldwide, geothermal technology will stay in the forefront to supply energy by using the earth's inner heat. [219]

Hazardous Materials (HAZMAT) Containers

NAWCWD Point Mugu was involved in helping develop new technologies for HAZMAT containers. These containers help the Navy comply with strict Resource Conservation and

Recovery Act regulations, as well as provide the Navy with a significant cost savings. During the first year of operation, for example, the Navy reduced its HAZMAT purchases from $132,000 to $55,000, with only one directorate participating in the program. The second year, purchases dropped to $43,000. More than 60 different types of HAZMAT containers are currently in use at Navy/Army/Air Force facilities around the world. They are also currently available on commercial carriers. [141] [230]

Health Monitoring System for Warfighters

NAWCWD researchers, in conjunction with Sun Biomedical Technologies (SunBMT), have developed novel data mining techniques for the early detection of disease. This new capability has the benefit of increasing both warfighter productivity and mission success rates. Warfighter productivity decreases during the symptomatic stage of any illness. Early detection, along with proper medical care, greatly reduces the duration of the illness. Also, missions can be compromised if critical personnel are noticeably ill during the mission. The gestation period for diseases can range from hours to years; therefore, the Warfighter may be unaware that he or she is sick prior to deployment. Testing essential personnel for disease before deployment will reduce the number of sick warfighters in the field. The procedure created by NAWCWD and SunBMT accomplishes these goals by using a small blood sample to reliably predict disease occurrence before the onset of symptoms.

This new technology is based on the emerging fields of pattern diagnostics, in which specific proteomic and genomic expression profiles are used to classify an individual as sick or healthy. Exposure to a disease is manifested in cellular and molecular changes, and these changes are specific for each disease type. Given the complexity of the human proteome/genome, however, it is challenging to assess the global cellular changes that occur following disease exposure. Using high-resolution and comprehensive analytical techniques to identify the proteins and their relative abundance in blood samples, together with sensitive data mining algorithms, makes it possible to characterize these changes and utilize them for disease prediction.

Improved Soldering Technology

During the 1970s, NAWCWD 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 effort 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 NAWCWD 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. [130]

Injection Loading of Energetic Materials

NAWCWD China Lake began developing injection loading technology in the mid-1980s to meet the Navy's IM requirements. This process provided a valuable means of loading explosives into

munitions, thus providing a greater range of loadable viscosities and consistent load quality. For plastic-bonded explosives, injection loading is much faster than conventional casting methods. China Lake also built a bench-scale injection loader in 1986, which was certified in 1995 for live operation. The injection loader has been in operation since and is also applicable to the propellant industry. [149]

Lead-Free Electric Primer

NAWCWD developed and optimized a lead-free primer formulation using nano-aluminum and molybdenum trioxide, a formulation that is one of two likely candidates for integration into industry as a replacement for lead primers in electrically primed ammunition. In testing and characterization, these primers have shown very positive results and meet DoD specifications. Thus, NAWCWD's efforts have led to a safer primer with better resistance to aging.

Approximately 1.5 billion rounds of small- and medium-caliber ammunition are fired by the U.S. military each year, and the DoD has a costly Environmental Protection Agency clean-up problem involving lead contamination in indoor and outdoor ranges. To help solve this problem NAWCWD is leading a team of researchers from LANL, Picatinny Arsenal, Lake City Army Ammunition Plant, Novacentrix, and General Dynamics Ordnance and Tactical Systems to validate and initiate transition of a new technology that would use nanoscale materials to develop environmentally acceptable lead-free primers for medium-caliber applications.

The refinement of the primer mix could also be transitioned to industry. Naval researchers at Indian Head, Maryland, and the Army are also evaluating an alternate candidate containing nano-aluminum and bismuth oxide. [172]

Logarithmic Amplifiers

The first ultrasonic body scanner was pioneered at China Lake during the late 1960s and early 1970s. Logarithmic nonlinear amplifiers 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, NAWCWD China Lake 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 since become a very important noninvasive medical diagnostic tool used worldwide. [130]

Natural Pumice

The Ordnance Evaluation Branch at NAWCWD China Lake was the first branch of the U.S. Government to use pumice to protect assets and personnel, with three patents awarded. NAWCWD first discovered the useful effects of pumice in the late 1970s while performing sympathetic detonation research. Engineers discovered that pumice, a volcanic ash created as lava cools, is readily found on the China Lake ranges. Pumice is very accessible, easy to use, and inexpensive. It contains thin membranes with enclosed air-filled cells and is naturally effective at absorbing shock, deflecting blasts, and preventing sympathetic detonation of explosives, thus

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 NAWCWD, natural ash is screened and inserted in its natural state inside thin container walls. Pumice containers can store more types of explosives in closer quarters, and these containers are currently used by rapid-response teams in all military branches, as well as by the Fleet, for safe packaging, transportation, and storage. In 2002, NAWCWD received congressional funding to continue research and development with pumice technology for various applications. [150]

Toxic Metal Removal From Storm Water

In 2006, NAWCWD researchers invented and patented a method for removing toxic metals from storm water runoff to provide clean water. The treatment facility includes a pretreatment chamber for removing large toxic particles and an absorption chamber for removing fine particles of toxic metals. The absorption chamber has a bed of three absorptive materials for removing the fine particles. This invention can be easily adapted for use at any military or industrial facility. [172]

Sensors in Automotive Air Bags

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. NAWCWD China Lake engineers conceived of an extremely robust and precise micro-machined miniature accelerometer. Working with a Small Business Innovative Research contractor, NAWCWD oversaw development using microelectronic fabrication techniques (to ensure ease of manufacture and lower 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 SADs. This device subsequently transitioned into millions of automobile crash-sensor air-bag-initiation systems by major foreign and domestic automobile manufacturers. The device is also used for hundreds of other consumer and industrial applications and is marketed internationally. [42]

Stop-Action Electromechanical Shuttered Video Cameras

In 1975, China Lake test range personnel devised an invention to provide non-smeared stop-action images of high-speed video events to allow accurate position-versus-time measurements. This technology also reduced cost compared to high-speed film cameras. The method was originally developed for vidicon tube cameras, but methods to achieve the same results with charge coupled device video cameras were also developed. A patent was awarded in 1977. 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). [158]

Supersonic Combustion Heating Apparatus

NAWCWD researchers were awarded a patent in 2005 for an invention that includes a sidewall

cavity with an advanced mixing system with ground-based oxygen injection for hypersonic materials and engine testing. This invention enhances kinetics, produces an increased high-enthalpy flow source, enhances flame stability, improves mixing between fuel and air, and shortens chemical ignition delay, without the use of expensive film-cooled nozzles. In addition, the Navy saves an estimated $2 million for each nozzle. [172]

Waste Incineration Technology

NAWCWD has developed and demonstrated an efficient high-temperature waste incineration technology. This technology allows smaller units to incinerate larger amounts of waste, thus using less fuel and resulting in fewer by-products than current commercial incineration processes. While investigating airbreathing (ramjet) combustion technology for aircraft and missile applications, NAWCWD researchers 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 into small portable combustion units for on-site waste incineration, thus eliminating the storage and transfer costs associated with removing waste to central locations. [41]

Cooperative Research and Development Agreements (CRADAs)

As our adversaries have adopted increasingly innovative tactics to disable coalition forces and impede their mission, the DoD has turned to one of its greatest assets, research and development, to counter these threats. NAWCWD has exploited CRADAs as mission extenders to leverage the capabilities of private industry in this endeavor. Several of the CRADAs recently executed in conjunction with this initiative are addressing specific force protection requirements. Through a series of CRADAs with different manufacturers, for example, NAWCWD is investigating use of lightweight armor materials to protect the occupants of HMMWVs, while preserving the vehicles' durability and off-road performance. One CRADA is investigating the feasibility of using directed energy to disable the electronic triggering mechanisms of IEDs, a technology that may also have potential for standoff detection of IED command wires. Another CRADA explores the feasibility of achieving standoff detection of sniper scopes and optical surveillance equipment. [193]

Since the early 1990s, the number of CRADAs at NAWCWD has continued to escalate, with revenues in excess of $20 million, which represented a potential cost avoidance to the Navy of more than $66 million. Most agreements involve military-related technology; however, some CRADAs involve commercial and educational projects. For example, a CRADA with the University of California, Santa Barbara (UCSB), enables the transfer of specialized radar technology from UCSB to the Navy for the purpose of mapping ocean surface currents and wave

heights in the vicinity of the Pacific Test Range. Another CRADA effort teams NAWCWD with a local medical research entity to explore the use of Navy-developed data mining and machine learning capabilities for medical diagnostic applications. Other significant CRADAs include a "TERM" ball joint seeker, integrated weapon system simulation, ESSM composite, Block IV fuze modification, guided Zuni rocket study, DPSS and Anti-Swimmer Grenade (ASG) development, counter-MANPADS research, and thermal battery research. [193]

Commercial Service Agreements (CSAs)

CSAs are agreements in which a government laboratory conducts testing or provides services for a domestic non-Federal-government customer. Under these agreements, the customer pays the government laboratory all direct and indirect costs incurred to accomplish the work. NAWCWD has authority to conduct such "fee for service" work efforts, when they are in the interest of national defense, under three federal statutes: Title 10 U.S.C. §§2539b, 2681, and 2563. NAWCWD is one of the few DoD laboratories able to work under all three statutes.

In the performance of its military mission, NAWCWD has acquired and developed specialized equipment and many one-of-a-kind facilities. With the addition of this center's dedicated scientists and engineers, the whole constitutes a significant scientific resource to industry. In fact, since the launch of NAWCWD's CSA program in 1997, the number of CSAs has climbed to more than 300, totaling more than $100 million. In fiscal year 2010 alone, 21 CSAs were enacted, with a total estimated value of $4.7 million.

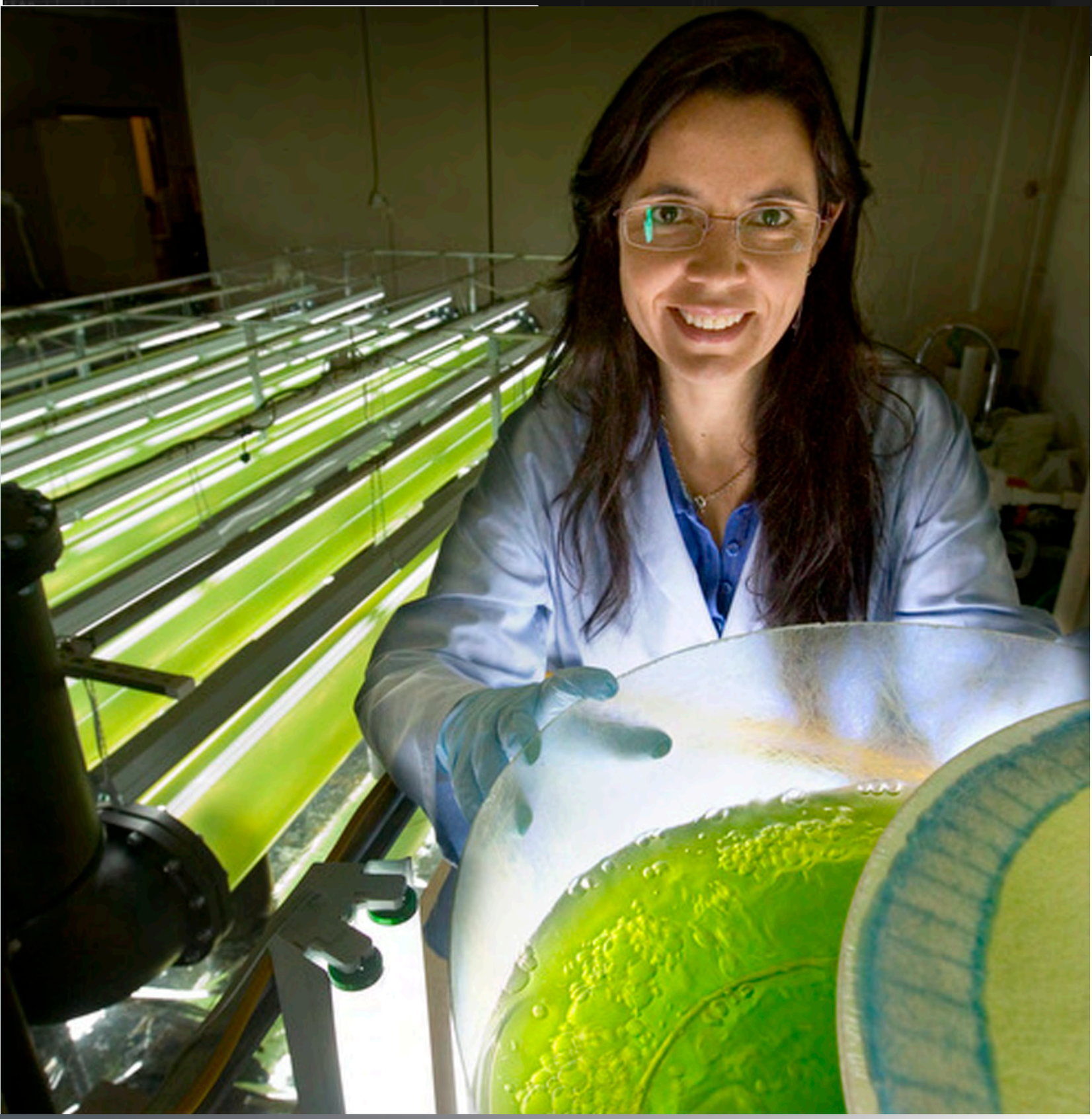
Educational Partnership Agreements (EPAs)

EPAs provide a mechanism for local education agencies, colleges, universities, and nonprofit institutions dedicated to improving science, mathematics, and engineering skills to take advantage of NAWCWD staff's expertise, unique facilities, and equipment related to naval warfare systems and technologies. A primary goal of EPAs is for NAWCWD scientists and engineers to encourage and facilitate early interest in the sciences and engineering by young people at all stages of their academic careers. EPAs provide a formal vehicle for information exchange, access to state-of-the-art facilities and technology, and research experiences. NAWCWD has ongoing EPAs with Sierra Sands Unified School District and Cerro Coso Community College, which are both located in Ridgecrest, California, as well as with New Mexico Institute of Mining and Technology, California State University Channel Islands, and California State University Northridge. [43]

Patents With Commercial Potential

Since the 1940s, scientists and engineers have created hundreds of inventions to solve technical problems associated with weapon development. From 1959 to 2010, more than 1,500 patents have been issued at NAWCWD. Several NAWCWD inventors hold more than 20 patents. [203]

Energy Strategy



Energy Strategy

Rear Admiral Mathias W. Winter, NAWCWD Commander, released the NAWCWD energy strategy in support of Secretary of the Navy's (SECNAV's) energy vision. Central to this strategy is NAWCWD's focus on mission-compatible energy technologies, both at the installation and operational level. In addition, NAWCWD looks to partner with industry, academia, and other DoD activities to bring new energy technologies to the Warfighter. Steps being taken by NAWCWD in support of the SECNAV's energy goals include the following:

- **Implementing energy-efficient acquisition policies.** NAWCWD is answering the call by using energy-efficient products and manufacturing capabilities.
- **Sailing the "Great Green Fleet."** NAWCWD is conducting RDT&E of biofuels and advanced fuel technologies. Additionally, biomaterial technologies to replace petroleum-based plastics and materials are being developed in the laboratories. The goal is to power jet, tactical, and non-tactical assets with biofuels by 2020.
- **Reducing non-tactical petroleum use 50% by 2015.** Remote range photovoltaic power, biofuel-powered generators, and advanced energy storage systems will replace diesel generators.
- **Increasing alternative energy ashore 50% by 2020.** Advancements at the Coso geothermal power plant have resulted in the generation of 200 megawatts per year of clean energy, and solar roofs throughout the Command are decreasing electric usage dramatically. A large solar farm at China Lake is in development.
- **Increasing total alternative energy usage by 50% by 2020.** A new Mission Compatibility Analysis Tool has been produced to characterize alternative energy developments around DoD installations. "Stealth" wind technology is being researched in conjunction with industry and academic partners, and smart metering initiatives are under way. Facilities and remote operations have solar photovoltaic installations to increase alternative energy generation.

RDT&E of Energy Technologies

Biofuel Research

Rear Admiral Mathias W. Winter signed a CRADA with Cobalt Technologies, Inc., a Bay Area company, for the development of a Navy biofuel. Biomass waste could soon be transformed into the bio-jet fuel of choice. Research chemists at China Lake have developed proprietary processes for converting the sugar alcohol n-butanol (which is harvested from plant waste material) into jet and diesel fuel.

Renewable Energy Technologies

NAWCWD, with industrial and academic partners, is developing next-generation energy solutions for the Warfighter in the areas of advanced energy storage and generation technologies to harvest the power of the sun and water, solar generation systems to support expeditionary and tactical operations, micro-grid technologies to increase installation and operational energy security, and technologies to convert waste streams into energy and power, as well as pioneering the cutting-edge fields of solar-powered and biofuel-powered UxS.

Geothermal Energy

Today, the Coso geothermal power plant is a world-class Navy resource, with total savings to NAWCWD exceeding $36 million. The Coso geothermal power plant produces enough power for 330,000+ homes. Scientists at China Lake were assigned the lead role for Navy geothermal efforts, even those not geographically limited to China Lake. As environmental concerns continue to shift toward “greener” power sources worldwide, geothermal technology will stay at the forefront to supply energy by using the earth’s inner heat.

Other Energy Initiatives

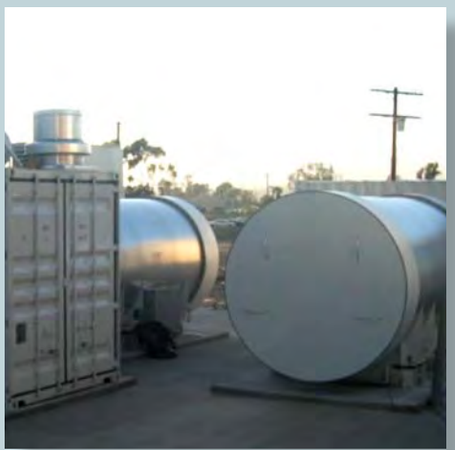
Solar Farm at Santa Cruz Island

Santa Cruz Island, located 30 miles off the coast of Point Mugu, has three photovoltaic systems providing power to remote facilities. One of these is a 150-kilowatt battery system that provides power to radar and communication equipment. In addition, a second photovoltaic system provides power to pump water to the highest point on the island, which is located 8.5 miles from the water well, and a third project includes a 30-kilowatt portable photovoltaic and battery system.

Photovoltaic Carports and Other Solar Thermal Projects

New photovoltaic carports and other solar thermal projects save the Navy more than $1 million annually. These projects were sponsored by an award from the American Recovery and Reinvestment Act of 2009, with the intent of reducing the carbon footprint and energy consumption of the base. Very large carport-mounted solar photovoltaic structures were installed in three of the largest parking lots on base, including those at Michelson Laboratory (155 kilowatts), Armitage Field (248 kilowatts), and Range Headquarters (230 kilowatts). The solar systems supply power to the buildings and feed energy back into the power grid when there is excess electricity produced. All the solar photovoltaic projects at China Lake combined should generate approximately 1 megawatt of annual renewable energy.

Project for 750-Kilowatt Molten Carbonate Fuel Cell Demonstrator at Marine Corps Base (MCB) Camp Pendleton



Integral to the renewable energy strategy, NAWCWD's Renewable Energy Laboratory is often called upon by other DoD partners to provide expertise and consultation regarding energy technology RDT&E. As an example, the 750-kilowatt fuel cell demonstration at Camp Pendleton was spearheaded by NAWCWD's scientists and engineers. The system provides base load power and heat, with environmental and energy security benefits.

Proton Exchange Membrane Fuel Cell Project at China Lake

NAWCWD engineers have been demonstrating new ways to store energy for use at night. Instead of acid-based batteries, the system is built around a hydrogen fuel cell. Electricity generated during the day powers an electrolyzer to generate hydrogen fuel from water. When the sun is no longer generating electricity in the panels, the fuel cell kicks in to generate power from the stored hydrogen. Currently, the Renewable Energy Laboratory at China Lake is optimizing the system to increase efficiency and reduce costs.

“First and foremost, energy conservation extends tactical range of our forces while also preserving precious resources. Our goal, as a Navy, is to be an ‘early adopter’ of new technologies that enhance national security in an environmentally sustainable way.”

—Rear Admiral Philip Cullom
Director of the Chief of Naval Operations Energy
and Environmental Readiness Division

Special Weapons and Projects

Special Weapons and Projects

NAWCWD's primary mission is to develop weapons for the Navy; however, NAWCWD also has extensive experience in developing and testing military components and subsystems that have direct applications to other missions, such as space or oceanography. Although work for other government agencies, such as NASA, represents only a very small fraction of the work performed by NAWCWD, the contributions made by China Lake and Point Mugu to these projects were vital to their successes.

China Lake Space Support

China Lake has a long association with NASA, applying its expertise in weapons development to the goal of space exploration.

Satellite and Probe Support

In 1957, the Soviet Union launched the first artificial satellite, Sputnik, into a low-Earth orbit. In response, China Lake made six attempts to launch NOTSNIK, a missile and payload designed and built by China Lake, into orbit. A pilot flew at 40,000 feet and then initiated a steep climb to 70,000 feet, at which point the rocket was launched, thrusting NOTSNIK into the atmosphere. Six launches took place over the Sea Range at Point Mugu. While five launches clearly failed to enter the Earth's orbit, one NOTSNIK satellite reportedly entered the orbit, according to Dr. John Nicolaides, the former Technical Director of the Navy's Space Program in the Bureau of Ordnance in Washington, D.C. [47]

China Lake was also the first to develop technology for satellite reconnaissance that allowed electronic images to be sent back to Earth from space. Because of this technology, NASA was also able to transmit electronic images of the back side of the Moon to Earth. In addition, 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. [152]

The SNORT facility at China Lake was used for numerous NASA tests, including testing the Gemini spacecraft, testing the parachute for the Space Shuttle's solid rocket boosters, and designing and evaluating an emergency escape system for the Space Shuttle. Another project for NASA was developing a parachute system in the 1980s for Galileo's atmospheric probes, which were dropped into planet Jupiter's atmosphere in 1995. The parachutes helped to slow the probes' descent as they gathered atmospheric data before being overcome by Jupiter's high temperatures and pressures. [203]

Lunar Support

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 did not 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 the vehicle approached the surface. In addition, China Lake ranges were used as a test track for the lunar rover because of its similar terrain.

When scientists wanted to simulate earthquakes on the Moon, NASA funded China Lake to develop the propellant for a series of mortars that astronauts left on the Moon. These mortars were later fired remotely from Earth to provide "moonquakes" for scientific study. China Lake was the only laboratory with the propellant technology to meet NASA's rigid requirements (i.e., the propellant had to endure the Moon's frigid vacuum for 7 weeks prior to being ignited). [46] [203]

Mars Mission Support

China Lake fabricated the rocket-assisted deceleration landing package tether system that was used in the successful Pathfinder landing on Mars in 1997. China Lake also designed, built, and assisted in the installation of the Zylon bridle system that connected the Mars exploration rover (MER) back shell to the lander. Each bridle contained 22 digital communication wires, thus allowing each lander to command the retro-rockets perfectly. Zylon, a new ultra-high-strength fiber, was subjected to strength and environmental testing. China Lake fabricated the prototypes, conducted qualification tests, and then fabricated three flight-quality units (plus a "flight spare") to support the two MER missions.

China Lake also supported the MER project by designing the descent rate limiters (DRLs), which allowed the lander to slowly drop to the end of the bridle; testing the radar systems that were used in timing air bag deployment and retro-rocket ignition; testing the retro-rockets that slowed both landers' descent; and conducting multi-body tests that involved the parachutes, back shells, and landers, which were connected by lines and bridles into a three-body system. When NASA's Jet Propulsion Laboratory (JPL) was interested in the dynamics that would result during the descent to Mars, China Lake built a simulated three-body test item and dropped it from a helicopter. Onboard and ground-based instruments and video captured the responses.

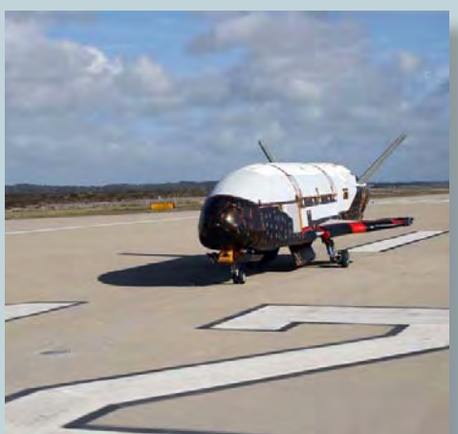
China Lake's support of the MER projects helped in the development of several technologies applicable to the Warfighter. Zylon lines, for example, may replace heavy, cumbersome aircraft tie-downs on carrier decks. The radar altimeter may also be considered for high-altitude low-opening parachute systems. In addition, the DRL is being considered for use in reusable reefing systems for Army cargo and Navy Special Operations Forces parachute systems.

Current NASA Project Support

NASA has funded China Lake in several different project areas:

- Designing and testing the Mars Science Laboratory (MSL) parachute, as well as developing and testing a new RF pyrotechnic line cutter device used for testing parachutes in the Ames Wind Tunnel Facility. The MSL is a Mars lander developed by the JPL that is much larger than the 2004 rovers and is designed to conduct a multitude of science experiments on the surface of Mars. One of the test requirements is for the parachute to be disreefed several times once the wind tunnel airflow reaches test velocity. Because this time always varies, the standard "fixed" time delay line cutters could not be used. China Lake developed a radio-frequency-triggered line cutter that allows the line cutter to be fired after the wind tunnel comes up to speed. The device is revolutionary in the parachute industry and will help immensely in other DoD parachute programs.

- Testing entry–descent–landing concepts for the next generation of Mars landers and, in association with JPL, developing a ground-based test bed to include a sophisticated multi-degree of-freedom dynamic simulator capable of full-size vehicle testing, as well as fabricating a test facility to conduct touchdown dynamic tests. China Lake is also working with NASA and other services on the IHPRPT to double rocket propulsion performance.



- Developing and testing a collapsible drogue parachute for NASA's X-37 Crew Return Vehicle (CRV) Test Program. During T&E operations, a B-52 aircraft flies to 45,000 feet and releases the CRV, which conducts practice maneuvers and eventually lands at Edwards AFB. To ensure that the CRV does not inadvertently recontact the B-52 after release, China Lake developed a drogue parachute separation system that released from the CRV seconds after separation from the B-52. Due to the high-altitude test requirements and the direction of prevailing winds at that altitude, a drogue chute collapse mechanism was also needed to prevent the drogue from drifting into Los Angeles International Airport's air corridor. This collapse mechanism consisted of ultra-low-temperature-capable silicone bands inside a Teflon cloth sleeve. The parachute system has currently undergone 14 parachute tests, ranging from the test of a single 10-foot-diameter pilot chute up to the system test of two 24-foot-diameter drogue parachutes, three pilot parachutes, and a cluster of three 116-foot-diameter final recovery parachutes. The collapsible drogue system was successfully tested at China Lake's HIVAS facility. [172]

Mini-RF—NASA's Leap Into Lunar Exploration

Four decades after humankind's first giant leap, NASA returned to the Moon in a big way with the Mini-RF project, which flew two radar instruments to map the lunar poles, to search for water ice, and to demonstrate new communication technologies. NAWCWD played an integral role in that effort.

An innovative SAR developed by China Lake orbited the Moon on two platforms: the Indian Space Research Organization's Chandrayaan-1 spacecraft (November 2008 through August 2009) and NASA's Lunar Reconnaissance Orbiter (LRO) (June 2009 to present). Chandrayaan made 3,400 orbits and sent back 70,000 images; and the LRO, still orbiting in 2011, has made more than 1,000 orbits and has obtained more than 192 terabytes (41,000 DVDs) of unprecedented detailed data. Ice deposits were detected on the Moon's north pole!

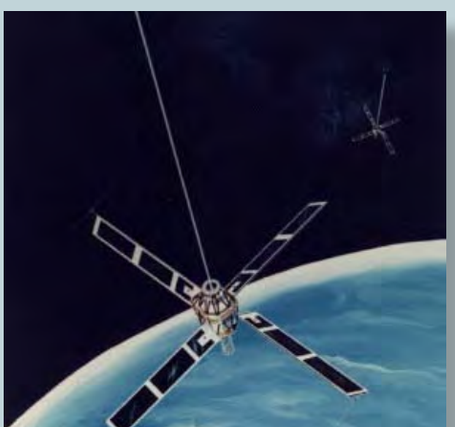
In addition, with images captured by the LRO camera, which provides ten times the resolution of any previous lunar camera, a new highly detailed topographical global map of the Moon was created, thus providing researchers worldwide with the best overview of the moon that we have ever had. We can now see rocks on the Moon that are only 2 feet in diameter.

The Mini-RF project focused on the mysterious and relatively unexplored regions that have significant exploration potential and have been chosen as the location of the next lunar mission. NAWCWD is proud to have been part of a diverse nationwide Mini-RF development and test team, which included government and university laboratories from across the United States.

Point Mugu Space Support

During Project Mercury, the nation's first manned orbiting space capsule, Point Mugu was involved in planning support for NASA. In addition, during the reentry of space capsules, four range ships equipped with instrumentation and two WV-2 aircraft used for telemetry data collection stayed at the Sea Range to recover the capsules at sea.

Satellite Support



In 1962, Point Mugu was commissioned to operate the Navy Navigation Satellite System, which was also referred to as the Transit system. Transit was the first satellite navigation system to be used operationally. It was primarily used by the U.S. Navy to provide accurate location information to its Polaris missile ballistic submarines, as well as a navigation system by the Navy's surface ships. The Applied Physics Laboratory of Johns Hopkins University originally developed Transit, and the system entered naval service in 1964. Point Mugu was one of the Navy's

tracking and injection stations for Transit. Due to GPS technology and improvements in electronics, the Transit system ceased navigation service in 1996. The Transit satellites were kept in use after 1996 as space-borne "mailboxes" and for the Navy Ionospheric Monitoring System. [51] [206]

Additional Space Program Support

Point Mugu also conducted drop tests on the Nuclear Emulsion Recovery Vehicle being developed by the Advanced Research Projects Agency (ARPA) for NASA. ARPA assigned additional projects to Point Mugu, including SARV Retro (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.

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 by exposing human subjects to a simulated 34,000-foot altitude for 5 days; this project also allowed researchers to test pressure suits and evaluate the effects of atmosphere, oxygen, and pressurization. In addition, Point Mugu studied bioacoustics to determine the effects of noise on humans. A staff of engineering psychologists examined the effects of high-energy acoustic levels involving the aircraft, missile, and impulse noise associated with naval weapons. Many safety changes were made as a result of these studies.

Point Mugu's support of MDA and Air Force ballistic launch programs has 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 into orbit and support of Mars space probes. [50]

Air Projects

High-Flying Research

In 1946, China Lake supported high-flying research. During the 4 years that B-29s were stationed at China Lake's Armitage Field, they flew 268 missions at altitudes up to 40,000 feet, for an estimated 600,000 miles. 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 China Lake received widespread recognition in the scientific community for its part in the program. [49]

Mountaintop Laboratory

In 1947, China Lake was looking for a high-altitude observation station to study the surface of the sun for solar flares, which were known to cause magnetic storms on earth and disrupt electrical communication systems. In 1948, China Lake built a laboratory near California's White Mountain. The construction crew blasted and bulldozed a 19-mile road up to a 12,242-foot elevation. The first two buildings, with elevations of 9,850 and 10,500 feet, opened in 1949. The laboratories have also been used for a variety of high-altitude tests, including Long Jump, which was a NAWCWD program that obtained IR

signatures of aircraft from a ground-based test station. Because of Mountaintop Laboratory's altitude, aircraft could fly toward the station from more than 50 miles away, while still remaining below the facility's altitude. Long Jump tests were conducted in 1985, 1986, 1988, and 1990. In Long Jump IV, 36 different sensors were tested and evaluated. [48]

In addition to the Long Jump tests, the laboratory used a cloud chamber at the site to obtain the world's first pictures of V particles, which are heavy, unstable subatomic particles. Also, a large mass spectrometer was installed to study the attenuation of sound waves. [49]

Undersea Projects

Anti-Swimmer Grenade (ASG) Program

Since the Vietnam conflict, enemy swimmers have been a threat to naval and commercial ships by placing explosives on their hulls. The MK3A2 concussion grenade, which is very effective against enemy soldiers in bunkers, buildings, and underground passages, has been the main weapon used against enemy swimmers. These grenades, however, are meant for use in buildings or on the battlefield, not for underwater use, so a suitable replacement was needed.

During 2004, NAWCWD developed and demonstrated a prototype grenade to engage underwater attackers that incorporates electronics for detecting desired depth and time to explode, as well as safeguards to prevent damage to personnel or ships. The hand-emplaced depth-activated ordnance device incorporates state-of-the-art safety and arming technology to meet the requirements for swimmer interdiction for port security. NAWCWD began design and development for concept demonstration, conducted underwater T&E to validate lethality, developed a test set to generate different sensor inputs, and performed open-air testing to validate functionality and to characterize the ability of the detonator to properly initiate the main charge.

NAWCWD first successfully demonstrated the ASG in 2007, and further testing demonstrated ASG's functionality at various depth settings. Testing was conducted at the Naval Surface Warfare Center Crane's Lake Glendora underwater ordnance facility. Under a CRADA, Kaman Aerospace modified the China Lake design in accordance with that company's best commercial practices. Additional analysis and testing are currently being conducted at the Naval Undersea Warfare Center at Newport to ensure the ASG is in accordance with federal Marine Mammal Protection Act standards. [172] [177]

Navy Marine Mammal Program (NMMP)

In the 1960s, China Lake and Point Mugu participated in the U.S. NMMP, which studied the way dolphins swim and communicate, as well as training them for high-risk tasks, such as deep-water

recovery and explosives placement. Because dolphins can make repeated dives to depths of hundreds of feet, have excellent directional hearing, and are not hindered by currents or reduced visibility, the animals were perfectly suited for naval operations.

Project Notty, named after the first Navy dolphin, generated further interest in dolphin capabilities, including trainability, intelligence, and communication. Notty was moved from her small aquarium tank in Los Angeles to an aquatic test facility at Point Mugu near the entrance of the Mugu Lagoon. This facility 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 collected other dolphins to train and later expanded the program to include sea lions and orcas.

Dolphins were also trained for nonmilitary tasks that were considered too difficult or dangerous for divers. For example, in 1965, a 270-pound bottlenose dolphin named Tuffy was trained to carry tools down to aquanauts stationed at SEALAB II, where they lived 200 feet below the surface for 30 days. During this time, Tuffy also brought back mail to the surface and had rescue duty training; a lost aquanaut could sound a buzzer to call Tuffy, who would dive down with a safety line.

In 1967, the NMMP and its Point Mugu facility were relocated to San Diego and were placed under the control of the Space and Naval Warfare Systems Center. [136] [232]

Torpedo Development

As a result of China Lake's expertise and reputation in both rocketry and underwater ordnance, the Bureau of Ordnance selected China Lake, with its facility at the Pasadena Annex, to conduct torpedo and other undersea projects. In the late 1940s, the Morris Dam facility at China Lake's Pasadena Annex helped designers develop new weapons for underwater operations. A torpedo shop, test pits, and an underwater cableway were constructed, and, in 1948, the ingenious variable angle launcher was dedicated, thus providing 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. China Lake first 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 product, the ASROC.

Other early torpedo projects developed by China Lake's Underwater Ordnance Department based at the Pasadena Annex included the rocket-assisted torpedo; Deep Jeep, the first U.S. manned submersible to descend more than 2,000 feet; the cable-controlled underwater recovery vehicle, which was a deep-water diving vehicle used for recovering torpedoes; and Moray, a two-man deep-diving test vehicle to explore concepts for small fighter submarines.

During the Vietnam conflict, China Lake conducted the Special Warfare Program (Swimmer) that carried out quick-response efforts supporting underwater demolition teams. A large array of specialized devices were developed at this time, including the actuation mine simulator for training and minesweeping. After the Vietnam conflict, torpedo component research and modification were emphasized, and studies in controls, structures, ballistics, and propulsion systems improved torpedo technology through the creation of new fabrication methods, head shapes, and propulsion fuels. Also during this time, China Lake developed two noteworthy torpedo propulsion systems: a pump-jet type and a hydro-turbojet type. NAWCWD continued work on complete torpedoes, notably the Mk 32, which was an active-homing torpedo for use against deep-running submarines, and the Mk 42, which was a deep-depth torpedo designed to be surface launched.

NAWCWD participated in other successful torpedo projects, including the Mk 46 torpedo, which was a high-speed, deep-diving antisubmarine torpedo capable of starting a helical search pattern for multiple re-attacks if the first pass was not successful. The Mk 46 Mod 0 entered service in 1963, and the Mk 46 Mod 5A(SW) went to the Fleet in 1996. More than 1,000 Mk 46s remain in U.S. service today. [46]

Homeland Defense Projects

Coast Guard Support

NAWCWD, the 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 multiyear, multiphase effort to replace 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; NAWCWD has the engineering capabilities to outfit the UAVs with the specialized sensors and instrumentation required for the Coast Guard mission. In addition, the UAVs that are housed in

the existing hangar on the flight line would have immediate access to the operational and test areas, all within a secure, restricted airspace. [3]

Explosive Ordnance Disposal (EOD) Detachment

The EOD Detachment at China Lake provides emergency services to the flight line for ordnance on aircraft in the event of a mishap, accident, or bomb threat. That organization is also involved in force protection training and has served as cohost for the FBI Academy. The New York Fire Department bomb squad trained with the EOD group, as well as the California Highway Patrol. The EOD Detachment at China Lake operates the only thermal treatment facility for explosive hazardous waste permitted on the West Coast. Discussed during training were examples of improvised explosives and incendiaries and blast injury and response, as well as a case study of the Oklahoma City incident and the processing of bombing crime scenes. Also included was a field exercise in post-blast evidence recovery and device reconstruction. The EOD Detachment also provided support in construction and detonation of a 500-pound improvised "vehicle bomb" and arranged for practical training areas. [54] [76]

Federal Bureau of Investigations (FBI) Support

The FBI's Large-Vehicle Bomb Post-Blast Crime Scene School has often utilized the SNORT range at China Lake to simulate large detonations. In 2003, more than 1,000 pounds of deadly explosives were packed inside an empty bus and detonated at SNORT to replicate a terrorist attack, thereby creating a simulated crime scene. The relatively pristine range then allowed the FBI students to identify parts of the vehicle and the bomb after the explosion. This range offered the class experience and expertise that could not be taught in a large city. [54]

In addition to training personnel, the FBI uses China Lake technology for homeland defense. For example, shoulder-launched IR-guided MANPADS are a significant threat to the safety of commercial aircraft. NAWCWD proposed the Portable Resource for the Investigation of Suspected MANPADS (PRISM) System to identify locations where MANPADS could be launched toward aircraft. The FBI 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 in Huntsville, Alabama. [54]

Underwater Hazardous Device Team (UHDT) Support

The Explosive Ordnance Disposal Mobile Unit (EODMU) Detachment at Point Mugu regularly works with the UHDT ONE, based out of Los Angeles. UHDT ONE is composed of FBI, Los Angeles Sheriff Department, and Los Angeles Police Department bomb technician divers whose job it is to locate, designate, and dispose of underwater IEDs. UHDT ONE responds to any nonmilitary/commercial

port threat occurring within the Los Angeles area. EODMU 3 Detachment personnel at Point Mugu use remote-controlled robots to perform downrange work that could put that group in harm's way. The detachment also uses Segways that help them get to potentially dangerous devices in less time and with less effort than if they were walking long distances wearing heavy bomb suits. EODMU technicians locate, identify, render safe, and explosively dispose of foreign and domestic ordnance, including conventional, chemical, biological, nuclear, underwater, and terrorist-type devices. [191]

Table of NAWCWD-Influenced Weapons in Conflict

During every major U.S. military crisis 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!

✓ = 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 Weapons Nonnuclear Components									◯
FAE	✓	✓	✓	✓	✓	◯	◯		
Fleet Ballistic Missiles	✓	✓	✓	✓	✓	✓	✓		
Gator		✓	✓	◯	✓	◯			
General Purpose Bombs	◯	◯	◯	◯	◯	◯	◯	◯	◯
HARM	◯	◯	◯	◯	◯	◯			
Harpoon, SLAM, SLAM-ER	◯	◯	◯	✓	✓	◯			
Hellfire	◯	◯	◯	◯	◯	◯			
JDAM	◯	◯	◯						
JSOW	◯	◯	✓	✓					
LGBs	◯	◯	◯	◯	◯	◯	◯		
Maverick	◯	◯	◯	◯	◯	◯	◯		
Phalanx	✓	✓	✓	✓	✓	✓			
Phoenix	✓	✓	✓	✓	✓	✓			
Rockets	◯	◯	◯	◯	◯	◯	◯	◯	◯
RAM	✓	✓	✓	✓	✓				
Shrike	✓	✓	✓	✓	✓	◯	◯		
Sidewinder	✓	✓	✓	✓	◯	◯	◯		
Skipper						◯			
Sparrow, SeaSparrow, ESSM	✓	✓	✓	◯	✓	◯	◯		
Standard Missile	✓	✓	✓	✓	✓	✓	◯		
Tomahawk	◯	◯	◯	◯	◯	◯			
Walleye	✓	✓	✓	✓	✓	◯	◯		

NOTE: **Middle East and Falklands missions, Iran/Iraq War, Cuban Missile Crisis—** Although direct combat involvement by United States 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.

Acronyms

AARGM	Advanced Anti-Radiation Guided Missile
AEGIS	Airborne Early Warning Ground Integration System
AESA	Active Electronically Scanned Array
AFB	Air Force Base
AFCS	Airborne Fire Control System
AFD	arm-and-fire device
AFSERS	Air Force Synthetic Environment for Reconnaissance and Surveillance
AIAA	American Institute of Aeronautics and Astronautics
AMRAAM	Advanced Medium-Range Air-to-Air Missile
AOT	advanced oxidation technology
APAM	Antipersonnel/Anti-Materiel
APKWS	Advanced Precision Kill Weapon System
ARM	anti-radiation missile
ARPA	Advanced Research Projects Agency
ARPDD	automatic radar periscope detection and discrimination
ASG	Anti-Swimmer Grenade
ASRAAM	Advanced Short-Range Air-to-Air Missile
ASROC	Antisubmarine Rocket
ASW	antisubmarine warfare
ATAR	Antitank Aircraft Rocket
ATARS	Advanced Tactical Airborne Reconnaissance System
ATFLIR	Advanced Targeting Forward-Looking Infrared
AWL	Advanced Weapons Laboratory
BAC	bistatic anechoic chamber
BIT	built-in test
BOAR	Bombardment Aircraft Rocket
Caltech	California Institute of Technology
CBU	cluster bomb unit
CEM	continuous emissions monitor
CES	combat environment simulation
CFC	chlorofluorocarbon
CIED	counter improvised explosive device
CL-20	hexanitrohexaazaisowurtzitane
CLPL	China Lake Propulsion Laboratories
CMBRE	Common Munitions Built-in-Test (BIT)/Reprogramming Equipment
CORPORAL	Collaborative On-Line Reconnaissance Provider Operationally Responsive Attack Link
CRADA	Cooperative Research and Development Agreement
CRV	crew return vehicle
CSA	Commercial Service Agreement
CSSQT	Combat System Ship Qualification Trial
CTS	command transmitter system
DAMASK	Direct Attack Munition Affordable Seeker
DARPA	Defense Advanced Research Projects Agency
DASH	Direct Attack Seeker Head
DEW	directed energy weapon
DGTDS	distributed ground-based threat detection system
DHACMD	Deployable Homeland Airborne Cruise Missile Defense
DMLGB	Dual-Mode Laser-Guided Bomb
DoD	Department of Defense
DPSS	Digital Precision Strike Suite
DREN	Defense Research and Engineering Network
DRL	descent rate limiter
DSLA	directed sound and light array
DT-1, -2, -3, -4	Developmental Test -1, -2, -3, -4
DTRA	Defense Threat Reduction Agency
EATS	Extended Area Test System
ECR	Electronic Combat Range
eESWA	Enterprise Expeditionary Strike Warfare Architecture
EFI	exploding foil initiator
EIPT	Energetics Integrated Product Team
ENIAC	Electronic Numerical Integrator and Calculator
EOD	explosive ordnance disposal
EODMU	Explosive Ordnance Disposal Mobile Unit
EPA	Educational Partnership Agreement
ESSM	Evolved SeaSparrow Missile
EW	electronic warfare
EWSSA	Electronic Warfare Software Support Activity
EWTES	Electronic Warfare Threat Environment Simulation

F2M2	Forward-Firing Miniature Munition
FAA	Federal Aviation Administration
FAE	fuel-air explosive
FBE	Fleet battle experiment
FBI	Federal Bureau of Investigation
FDE	forward dissemination element
FLC	Federal Laboratory Consortium
FLIR	forward-looking infrared
FMS	foreign military sales
FSL	Fire Sciences Laboratory
G2M	GPS-Guided Miniature Munition
GCU	guidance control unit
GHMD	Global Hawk Maritime Demonstration
GPS	Global Positioning System
GUI	graphical user's interface
HARM	High-Speed Anti-Radiation Missile
HAZMAT	hazardous materials
HEL	high-energy laser
HIVAS	High-Velocity Airflow System
HMMWV	High-Mobility Multipurpose Wheeled Vehicle
HSMST	High-Speed Maneuverable Seaborne Target
HSW	high-speed weapon
HTTP	Hypertext Transfer Protocol
HUD	heads-up display
HWIL	hardware-in-the-loop
IBAR	Integrated Battlespace Arena
ICAP II, III	Improved Capability II, III
ICBM	intercontinental ballistic missile
IED	improvised explosive device
IFPDAS	In-Flight Physiologic Data Acquisition System
IHPRPT	Integrated High Payoff Rocket Propulsion Technology
IM	insensitive munitions
IMTTP	Insensitive Munitions Technology Transition Program
INCANS	Interference Cancellation System
INS	inertial navigation system
IPT	Integrated Product Team
IR	infrared
ISR	intelligence, surveillance, and reconnaissance
ITALD	Improved Tactical Air-Launched Decoy
ITEC	Interoperability Test and Experimentation Complex
J-UCAS	Joint Unmanned Combat Air System
JABS	JDAM Assault Breaching System *[JDAM denotes Joint Direct Attack Munition]*
JAGM	Joint Air-to-Ground Missile
JANNAF	Joint Army, Navy, NASA, and Air Force
JATO	Jet-Assisted Takeoff *[Team]*
JCIF	Joint Counter-IED Facility *[IED denotes improvised explosive device]*
JCTD	Joint Capability Technology Demonstration
JDAM	Joint Direct Attack Munition
JEFX06	Joint Expeditionary Force Exercise 2006
JHMCS	Joint Helmet-Mounted Cueing System
JIEDDO	Joint Improvised Explosive Device Defeat Organization
JMEWS	Joint Multi-Effects Warhead System
JMPS	Joint Mission Planning System
JNTC	Joint National Training Capabilities
JPL	Jet Propulsion Laboratory
JSF	Joint Strike Fighter
JSOW	Joint Standoff Weapon
JTCG/AS	Joint Technical Coordinating Group on Aircraft Survivability
JTFEX	Joint Fleet Exercise
JTRS	Joint Tactical Radio System
LANL	Los Alamos National Laboratory
LCDB	Low Collateral Damage Bomb, also known as LOCO
LEEFI	low-energy exploding foil initiator
LFT&E	live fire test and evaluation
LGB	laser-guided bomb
LJDAM	Laser Joint Direct Attack Munition
LOGIR	Low-Cost Guided Imaging Rocket
LRO	Lunar Reconnaissance Orbiter
M&S	modeling and simulation
MAC	metal augmented charge
MAD	Marine Aviation Detachment
MAE UAV	Medium-Altitude Endurance UAV *[UAV denotes Unmanned Aerial Vehicle]*
MAG-11	Marine Air Group 11
MANPADS	man-portable air-defense systems
MAVUS	maritimized vertical takeoff-and-landing UAV system *[UAV denotes unmanned aerial vehicle]*
MC02	Millennium Challenge 2002

MCB	Marine Corps Base
MCCL	Mobile Command and Control Laboratory
MDA	Missile Defense Agency
MEMS	microelectromechanical systems
MER	Mars exploration rover
MESA	Missile Engagement Simulation Arena
MGBU	Miniature Guided Bomb Unit
MIDS	Multifunctional Information Distribution System
MIRV	multiple independently targetable reentry vehicle
MOCS	Multilateration Operations Control System
MORPH	molecular photonic material
MOTT	Mobile Ordnance Training Team
MPBR	Multipurpose Bomb Rack
MSL	Mars Science Laboratory
MSS	Military Sensor Symposia
MST	Mobile Ship Target
MTI	moving target indicator
MUSE	Multiple Unified Simulation Environment
N-UCAS	Navy–Unmanned Combat Air System
NAMTC	Naval Air Missile Test Center
NAS	Naval Air Station
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NATO C3	NATO Consultation, Command, and Control *[NATO denotes North Atlantic Treaty Organization]*
NAVAIR	Naval Air Systems Command
NAVSEA	Naval Sea Systems Command
NAWCAD	Naval Air Warfare Center Aircraft Division
NAWCWD	Naval Air Warfare Center Weapons Division
NAWS	Naval Air Weapons Station
NCA	Navy Combat Archer
NELB	Navy Energetics Leadership Board
NGJ	Next-Generation Jammer
NLO	nonlinear optic
NLOP	nonlinear optical polymer
NMC	Naval Missile Center
NMMP	Navy Marine Mammal Program
NOTS	Naval Ordnance Test Station
NSAWC	Naval Strike and Air Warfare Center
NSW	Naval Special Warfare
NSWG	Naval Special Warfare Group
NTWP	Naval Test Wing Pacific
NWC	Naval Weapons Center
OFP	Operational Flight Program
ONR	Office of Naval Research
OPEVAL	operational evaluation
PGM	precision-guided munition
PMPT	Paveway Munitions Planning Tool
PMR	Pacific Missile Range
PMRF	Pacific Missile Range Facility
PMTC	Pacific Missile Test Center
PRISM	Portable Resource for the Investigation of Suspected MANPADS *[MANPADS denotes Man-Portable Air-Defense Systems]*
PSN	Precision Strike Navigator
PSS-SOF	Precision Strike Suite–Special Operations Forces
RAIDER	Rapid Attack Information Dissemination and Execution Relay
RAM	Rolling Airframe Missile
RAMICS	Rapid Airborne Mine Clearance System
RAPEC I, III	Rocket-Assisted Personnel Ejection Category I, III
RAT	Raven Advanced Targeting
RATTLRS	Revolutionary Approach to Time-Critical Long-Range Strike
RAYDAC	Raytheon Digital Automatic Computer
RCS	radar cross section
RDAT&E	research, development, acquisition, test, and evaluation
RDT&E	research, development, test, and evaluation
REAC	Reeves Electronic Analog Computer
RF	radio frequency
RIFs	Radiographic Inspection Facilities
RIMPAC	Rim of the Pacific
ROVER	Remotely Operated Video Enhanced Receiver
RPG	rocket-propelled grenade
RPTS	Rapid Precision Targeting System
RRL	Radar Reflectivity Laboratory
SAD	safety-and-arming device
SAM	surface-to-air missile

SAR	synthetic aperture radar
SDB	Small-Diameter Bomb
SDREN	Secret Defense Research and Engineering Network
SEAD	suppression of enemy air defense
SECNAV	Secretary of the Navy
SHARP	Shared Reconnaissance Pod
SIPRNET	Secure Internet Protocol Router Network
SLAM	Standoff Land Attack Missile
SLAM-ER	Standoff Land Attack Missile–Extended Response
SLBM	submarine-launched ballistic missile
SNORT	Supersonic Naval Ordnance Research Track
SRTGT	Shootable Remote Threat Ground Target
SSB	small smart bomb
SSBR	Spin-Stabilized Bombardment Rocket
START	Strategic Arms Reduction Treaty
STG	synthetic target generator
STUAS	small tactical unmanned aerial system
STWC	Strike Warfare Command Center
SunBMT	Sun Biomedical Technologies
SWAT	special weapons and tactics
T&E	test and evaluation
TALD	Tactical Air-Launched Decoy
TCS	tactical control system
TDD	target-detecting device
TDM	Tactical Dissemination Module
TIMS	Tomahawk In-Flight Missile Simulator
TJR	Tactical Jamming Receiver
TJS	Tactical Jamming System
TLAM-C	Tomahawk Land Attack Missile/Conventional
TLAM-N	Tomahawk Land Attack Missile/Nuclear
TNT	trinitrotoluene
TPO	Technical Project Office
TRUS	Tilt Rotor UAV System *[UAV denotes Unmanned Aerial Vehicle]*
TSPI	time, space, position information
TTNT	Tactical Targeting Network Technology
UAS	unmanned aerial system
UAV	unmanned aerial vehicle
UAV-MR	UAV–Medium Range *[UAV denotes Unmanned Aerial Vehicle]*
UCAS-D	Unmanned Combat Air System–Demonstration
UCAV	unmanned combat aerial vehicle
UCLASS	Unmanned Carrier-Launched Airborne Surveillance and Strike
UCSB	University of California, Santa Barbara
UE UAV HFE	Ultra Endurance Unmanned Aerial Vehicle Heavy Fuel Engine
UGV	unmanned ground vehicle
UHDT	Underwater Hazardous Device Team
USA	Unmanned Systems Activity
USF	Unmanned Systems Facility
USJFCOM	U.S. Joint Forces Command
USV	unmanned sea vehicle
UTTR	Utah Test and Training Range
UxS	unmanned systems
VLA	Vertical Launch ASROC *[ASROC denotes Antisubmarine Rocket]*
VLAP	Vietnam Laboratory Assistance Program
VLO	very low observable
VMC	visual meteorological conditions
VMR	Virtual Missile Range
VPF	Virtual Prototyping Facility
VTUAV	vertical takeoff unmanned aerial vehicle
WD	Weapons Division
WDL	weapon data link
WEO	Weapons Engagement Office
WEPTAC	Weapons and Tactics Analysis Center
WRC	Warfighter Response Center
WSCI	Weapons Systems Center for Integration
WSL	Weapons Survivability Laboratory
WSSA	Weapons Systems Support Activity

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Other requests. Submit to NAWCWD-PAO@navy.mil.

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Arming the Fleet
Providing Our Warfighters the Decisive Advantage
1943-2011

By
Wallace T. Martin

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