Premier Issue

NAVAL RESEARCH LABORATORY

SPECTRA

THE MAGAZINE OF THE NAVY'S CORPORATE LABORATORY

FALL 2010

SURVEILLANCE VEHICLES SOAR ON FUEL CELL POWER

CLIMATE CHANGE AND ALTERNATIVE FUELS IN THE ARCTIC

NAVY RESEARCHERS APPLY SCIENCE TO FIRE FIGHTING

NRL SCIENTIST COMMEMORATED IN CHRISTENING OF USNS *HOWARD O. LORENZEN*

THE LEADING EDGE

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NAVAL RESEARCH LABORATORY

Welcome to the first issue of SPECTRA, a magazine designed to inform you of the exciting science and technology being developed at the U.S. Naval Research Laboratory (NRL). Inside you will read about some of NRL's advances in the areas of systems, materials science, ocean and atmospheric sciences, and space science.

NRL was established early in the last century on the knowledge that technology and national security are strongly linked. It was Thomas Edison, commenting in 1915 on the war raging in Europe, who argued that we should look to science to keep the nation safe. "The Government," he proposed, "should maintain a great research laboratory." NRL became that laboratory, opening its doors in 1923.

Today, NRL's research programs span the scientific spectrum, including studies in biomolecular engineering, remote sensing, virtual reality, superconductivity, nanoscience, and solar corona monitoring. Indeed, NRL is the Navy's lead laboratory in space systems research, fire research, tactical electronic warfare, microelectronic devices, artificial intelligence, and research in ocean and atmospheric sciences. With more than 85 years of growth and development, NRL shines as the Navy's corporate laboratory and as one of the Federal Government's leading in-house centers for innovative research in the national interest.

NRL has helped make the U.S. Fleet the most formidable naval fighting force in the world, fulfilling Edison's vision with a record of technical excellence that has had a profound impact on national security.

We hope you enjoy SPECTRA and share it with others. Should you need additional copies, or like more information on the technologies discussed in the articles, please email spectra@nrl.navy.mil.

THE MAGAZINE OF THE NAVY'S CORPORATE LABORAT

NAVAL RESEARCH LABORATORY
SPECTRA

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Contents

FEATURES

ON THE COVER

XFC – *NRL's eXperimental Fuel Cell unmanned aerial vehicle. Stealth. Endurance. Clean Energy. See page 2.*

NEWS BRIEFS

Outreach

NRL at the Trade Shows

Technology and Innovation

Focus on People

The Last Word

Surveillance Vehicles Soar On Fuel Cell Power

Nearly undetectable from the ground, unmanned aerial vehicles (UAVs) are widely used by the military to scan terrain for intelligence and possible threats. Now, the Naval Research Laboratory is flying UAVs powered by high-energy fuel cells as part of an Office of Naval Research–sponsored program to help tactical decision-makers gather critical information more efficiently... more quietly… more safely.

A Concept Takes Flight

Piloted remotely or autonomously, unmanned aerial vehicles have long provided extra "eyes in the sky," especially for missions that are too dangerous for manned aircraft. At the Naval Research Laboratory (NRL), scientists are merging UAV technology and alternative energy research to develop advanced, fuel-cell-powered UAVs that can fly longer, lower, quieter, and farther than their traditionally powered counterparts, offering significant tactical advantages.

Building on its extensive experience developing battery-powered electric UAVs, NRL began research into fuel cell UAVs in 2003. Starting with a small, 100-watt fuel cell from Protonex Technology Corporation, an NRL team assembled a power system from off-the-shelf parts such as tubing and aluminum foil to make the radiator, and a tank from a paintball gun to hold high-pressure hydrogen for fuel. They retrofitted the system into a sailplane kit and called the vehicle the "Spider Lion." In its November 2005 demonstration flight, the 6-pound Spider Lion flew for 3.3 hours with only a half-ounce of hydrogen in its tank. Although the Spider Lion was far from a useful military vehicle — it had no payload and was not very durable — it showed that fuel-cell-powered flight was possible for UAVs.

The late James Kellogg, NRL engineer, with the Spider Lion, which flew for 3 hours and 19 minutes on a half-ounce of hydrogen fuel.

Why Fuel Cells?

Fuel cells offer clean, quiet, high-efficiency electric power for UAVs. Proton exchange membrane (PEM) fuel cells, also called polymer fuel cells, are electrochemical devices that create an electric current when they combine hydrogen and oxygen to make water. They consume only hydrogen and air, and their only emissions are water and heat.

Fuel cells are two to three times more efficient than internal combustion engines, and have much greater endurance than batteries. While batteries provide quiet and reliable electrical energy, and are used to power many of

The XFC unmanned aerial vehicle in flight.

the small UAVs on the battlefield today, their low endurance translates into less time collecting intelligence and more time spent on "refueling" and turn-around. Fuel cell systems overcome these limitations.

The Navy is interested in harnessing fuel cell technology to increase power potential and energy efficiency across its operational spectrum — from air vehicles to ground vehicles to undersea vehicles; to man-portable power generation for Marine expeditionary missions; to meeting power needs afloat.

The Office of Naval Research (ONR), a major sponsor of NRL's fuel cell research, has been supporting the development of innovative power and energy technologies for decades. *"Pursuing energy efficiency and energy independence are core to ONR's Power and Energy Focus Area,"* said Rear Admiral Nevin Carr, Chief of Naval Research. *"ONR's investments in alternative energy sources, like fuel cell research, have application to the Navy and Marine Corps mission in future UAVs and vehicles. These investments also contribute directly to solving some of the same technology challenges faced at the national level."*

Lightweight, Durable, and Stealthy: XFC

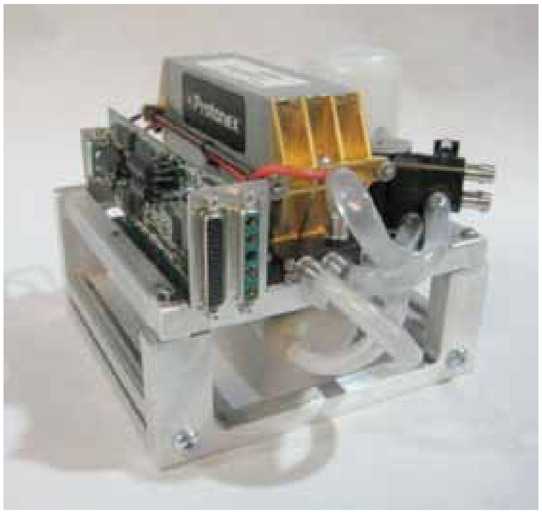
In 2006, through sponsorship of ONR and the Office of the Secretary of Defense's Rapid Reaction Technology Office and Office of Technology Transition, NRL partnered with Protonex Technology Corporation to design and build a hydrogen fuel cell power plant for a battlefield-capable, payload-carrying UAV. They aimed to put the most power they could into the smallest and lightest package possible.

The team first tested a new 2.2-pound, 300-watt fuel cell system onboard the eXperimental Fuel Cell unmanned aerial system, or XFC UAS. NRL's Chemistry and Tactical Electronic Warfare divisions developed the XFC UAS as an affordably expendable surveillance platform. It is a folding-wing UAV that ejects from an 18" diameter transport tube and unfolds to its X-shaped flight configuration after launch. XFC is fully autonomous and weighs 19 pounds with a 2.5-pound payload. The hydrogen fuel cell generates all the power the XFC needs — for electric propulsion, command and control, avionics, and payload operation — and keeps it flying for longer than 6 hours.

The XFC is being further developed to be launched from a submerged submarine, both from a torpedo tube and from a vertical tube. It represents the military's first tactical fuel-cell-powered UAV.

The Ion Tiger Aims Higher

The next step was to improve the fuel cell design to enable a longer mission with a heavier payload — this time on a vehicle called the Ion Tiger. For the Ion Tiger UAV, the mission goal was to fly for 24 hours and carry a 5-pound payload — the approximate weight of common payloads such as a day/night camera or a communication relay.



The 2.2-pound, 550-watt polymer fuel cell developed by Protonex Technology Corporation.

NRL again teamed with Protonex Technology Corporation to improve the fuel cell system, along with the University of Hawaii for systems testing and modeling, HyperComp Engineering to build the hydrogen tanks, and Arcturus UAV to build the airframe. The team designed a 37-pound vehicle with a 17-foot wingspan, allowing 13 pounds

Inside the Ion Tiger: the hydrogen tank and regulator are on the right; the radiator is on the left. The fuel cell is underneath the radiator.

for a fuel cell system, hydrogen tank, and regulator. The new 550-watt (0.75 horsepower) fuel cell system still weighed only 2.2 pounds, but now was more efficient, converting 99 percent of the hydrogen fuel to electricity at 40 to 55 percent efficiency. NRL developed thermal and systems models and new methods to make custom hydrogen fuel tanks, making the entire fuel cell system design modular so it can be adapted to a variety of military and commercial platforms.

In October 2009, at the U.S. Army's Aberdeen Proving Ground on the northwestern shore of Maryland's Chesapeake Bay, the Ion Tiger was launched for its much-anticipated test flight. The UAV stayed aloft for 23 hours and 17 minutes to set an unofficial endurance record for fuel-cell-powered flight, despite stormy and windy weather conditions. The Ion Tiger was flown again in November 2009 for an unprecedented 26 hours and 1 minute, beating its previous record and exceeding program goals.

Through these demonstrations, NRL proved that polymer fuel cell technology can meet or surpass the performance of traditional power systems. In fact, the Ion Tiger fuel cell system provided seven times the endurance of the equivalent weight in batteries. *"This is something that, until now, has not been achieved by anyone,"* said ONR Program Manager Dr. Michele Anderson. *"The Ion Tiger successfully demonstrates ONR's vision to show how efficient, clean technology can be used to improve the warfighter's capabilities."*

NRL has come a long way since that first Spider Lion flight. *"Today,"* says NRL's principal investigator for alternative energy research, Dr. Karen Swider-Lyons, *"these long-endurance flights are made possible by the team's sustained research on high-power fuel cell systems, lightweight hydrogen-gas storage tanks, improved thermal management, and the effective integration of these systems."*

The Ion Tiger being launched for its October 2009 test flight.

The Sky's the Limit

NRL scientists and engineers are already working on the next generation of fuel cell UAVs. They are focusing on tripling the flight endurance of the present power system by using cryogenic liquid hydrogen, which can be stored at about a third the weight of the compressed hydrogen gas. They are also exploring a larger system with a 1.5-kilowatt (2-horsepower) fuel cell capable of carrying a 15- to 30-pound payload.

Military planners want these stealthy, more capable, fuel-cell-powered UAVs. These aircraft will be able to stay on station for long periods of time, supplying commanders with continuous surveillance. Their long endurance will enable them to serve as communication relays. Their quiet propulsion will allow them to fly undetected at low altitudes, and thus perform high-quality surveillance with low-resolution imaging systems. The hydrogen fuel can be electrolyzed directly from seawater onboard Navy ships, so these UAVs could reduce some of the logistics burdens associated with traditional fuels.

The ultimate benefit will be to replace large, manned aircraft with smaller, less expensive fuel cell UAVs — keeping more personnel out of harm's way and improving tactical capabilities, all by using a "green," quiet, efficient, and affordable fuel system.

The Ion Tiger flight team after the 23-hour flight at Aberdeen Proving Ground in October 2009. Standing, left to right: Dan Edwards and Kenny Booth, ground station flight controls; Drew Rodgers, fuel cell systems; Mike Schuette, hydrogen tanks, regulators; Dave Miller, Aberdeen Proving Ground; Alvin Cross, flight systems management; Karen Swider-Lyons, fuel cell systems. Kneeling, left to right: Joe Mackrell, airframe systems; Steve Carruthers, airframe integration and pilot; Chris Bovais, pilot. Not shown: Greg Page and Rick Foch, airframe designers; Rick Stroman, fuel cell systems; Mike Baur, ground station/flight controls.

Contributors to this article include Donna McKinney, Dick Thompson, and Daniel Parry (NRL Office of Public Affairs), with the assistance of Dr. Karen Swider-Lyons (NRL Chemistry Division).

NRL breaks ground for its

Laboratory for Autonomous Systems Research

NRL's Laboratory for Autonomous Systems Research will become a nerve center for highly innovative basic research for autonomous systems for the Navy and Marine Corps.

KEY S&T AREAS

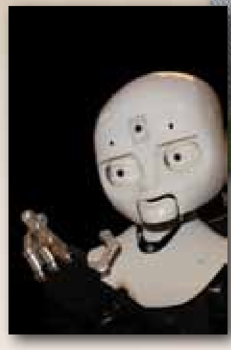
- Intelligent Autonomy
- Mobility
- Power and Energy
- Sensors
- Human-System Interaction
- Platforms
- Networking and Communications
- Trust and Assurance

Groundbreaking – April 8, 2010

forging the technology of tomorrow...

RESEARCH LABORATORIES

Intelligent Autonomy • Power and Energy • Sensors • Human-System Interaction



Because Autonomous Systems are not just vehicles, the building will contain a number of Human-System Interaction Labs to develop automated decision support tools and address critical communications and network issues.

The Power and Energy Lab will have a walk-in dry room for handling moisture-sensitive materials such as those used in lithium ion batteries.

Novel power sources such as fuel cells will be integrated into new systems and platforms.

The Sensor Lab will have facilities to calibrate and test many different types of chemical, biological, radiation, nuclear or explosives (CBRNE) sensors developed elsewhere at NRL and brought to this new building for integration into systems or platforms.

SIMULATED ENVIRONMENTS

Desert • Littoral • Tropical • Reconfigurable Prototyping

NRL's Micro Tactical Expendable "MITE" air vehicle.

The Reconfigurable High Bay will allow real-time, accurate tracking of many entities (vehicles and humans) for experimental ground truth. Small UAVs and ground vehicles can simultaneously operate within the large high bay, which is viewable from four adjacent human-system interaction labs. The lab will also have pseudo-GPS and a surround sound system to allow emulation of environmental noises.

The Tropical High Bay will provide a simulated jungle terrain and rain forest including a flowing water feature in an enclosed greenhouse-type structure. An adjacent outdoor area features an upland forest.

The Littoral High Bay will provide a simulated coastal environment featuring mud/sediment pits (used to support the energy harvesting device shown in the picture), small flow and wave tanks, and a larger pool with a sloping floor.

The Desert High Bay will provide a simulated desert environment featuring a sand pit and rock wall plus variable levels of illumination, wind, and smoke.

From Takeoff to Landing: NRL First in U.S. History to Remotely Fly Pilotless Aircraft

Unmanned aerial vehicles, or UAVs, are becoming a greater force in today's military arsenal of reconnaissance and weaponry. Although the concept of using manned aerial platforms as a device of military strategy is many centuries old, the ability to fly an unmanned, full-size, powered aircraft remotely from the ground and return it safely to its departure point has been possible only since the 20th century.

As early as World War I (1914–1918), the U.S. military began to experiment with unmanned aircraft. Merely 10 years after the Wright brothers first flew in 1903, aviation entrepreneur and inventor Lawrence B. Sperry, building on the gyro-compass developed by his father Elmer Sperry, stunned civilian and military spectators at the 1914 Airplane Safety Competition (Concours de la Securité en Aéroplane) held in France. During a low-altitude pass, Sperry and his assistant, Emil Cachin, climbed onto the wings of the aircraft to demonstrate the enormously safe and stable operation of what became the modern autopilot.

Several years after this perilous display, Sperry continued to work with the U.S. Army Air Service toward the development of a pilotless, gyro-stabilized aircraft capable of fully unmanned flight for the purpose of delivering explosive ordnance over enemy lines without imperiling military aviators. In 1920, the Army, also working with inventor Charles Kettering on a similar vehicle called the "Kettering Bug," contracted with Sperry to build a small number of his lightweight Sperry aircraft, known as Sperry Messengers, solely for this purpose. The Army named this aircraft the Messenger Aerial Torpedo (MAT), a crude precursor to the cruise missile, and began field test trials to determine the accuracy and feasibility of this novel machine.

Flying with a safety pilot onboard for observation, the "drone" aircraft proved capable of short distance accuracy, but failed the Army requirements for greater distance navigation and accuracy due to the inability to correct for unpredictable wind direction and velocity. Sperry devised a solution that included adding radio-operated controls to the aircraft and began working with engineers at the Army Air Service's Radio Section. With the assistance of a controlling aircraft flying close by, the Sperry MATs successfully and with considerable accuracy were able to reach their targets and return. However, the addition of a manned controlling aircraft flying within a mile of the drone proved impractical and unsatisfactory to meet the original design and goals of the Army. With interest waning and the untimely and unrelated death of Lawrence Sperry in 1923, the decision was made a few years later to abandon the project.

Sperry's innovation and forward thinking did not go without recognition. The U.S. Navy, having similar interest in work being conducted by the Army, requisitioned a modified Curtiss N-9H floatplane from the project in 1920. The N-9H aircraft, a model already in use by the Navy, had been used in the latter part of testing by the Army due to their increased stability and load-carrying capabilities and were being housed at the Navy Proving Ground, Dahlgren, Virginia.

After considerable delay and skepticism that the pilotless aircraft would ever become a formidable military component, a board assembled by the Chief of Naval Operations, Rear Admiral Robert E. Coontz, made recommendation to the Secretary of the Navy, The Honorable Josephus Daniels, that further development of radio-controlled flights was possible through research being developed by the Bureau of Engineering under the direction of Albert Hoyt Taylor at the Naval Aircraft Radio Laboratory at Anacostia. Taylor, best known for his later work in the development of modern radar, had been assigned radio engineer Carlos B. (C.B.) Mirick; under the supervision of the Bureau of Ordnance the two were sent to Dahlgren in 1922 to begin retrofitting the acquired Curtiss aircraft for pilotless radio-controlled flight.

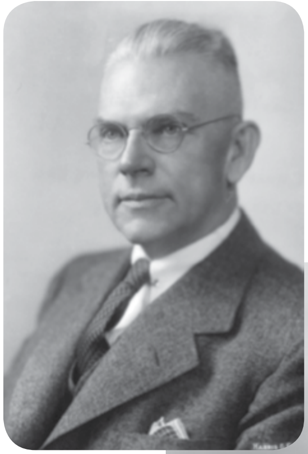
This U.S. Navy Curtiss N-9H floatplane was used in the first radio-controlled flight experiments at Dahlgren, Virginia, 1924.

Carl Norden, a former partner of Elmer and Lawrence Sperry and inventor of the flywheel catapult used in the Army's experiments with Sperry's aircraft, was called upon to assist the team assembled at Dahlgren. Building on the success of the gyro-stabilizer he helped develop at Sperry Aircraft, Norden continued to improve and modify automated control systems for aircraft (Norden later developed the historically significant

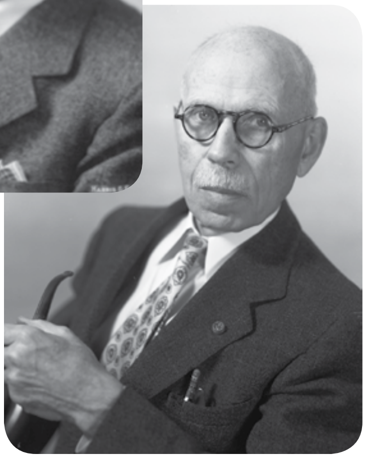
Norden bombsight used extensively during World War II). After review from the Dahlgren team, the Norden automatic pilot system was selected for the tests.

Mirick, experienced with the engineering challenges of aircraft radio – later developing a patented shielding design for electrical interference in aircraft – was delegated the responsibility of developing the radio control system to be mated to the Norden controls. In July 1923, now under the control of the newly created Naval Research Laboratory (NRL) in Washington, D.C., installation and testing of the radio equipment was completed. The equipment included a Morkum teletype operating on Baudot code, a continuous-wave transmitter, an amplified receiver, and numerous electrical relays and other ancillary components developed at the Naval Aircraft Radio Laboratory and NRL.

By November 1923, 33 radio-controlled flights had been successfully flown from a ground-based command post while naval aviator Lieutenant John J. Ballentine, whose Naval career later included advancement to Vice Admiral and Commander of the Sixth Fleet, Atlantic and Mediterranean, flew onboard as an observing safety pilot. A flight performed before senior officials of the Navy's Bureau of Ordnance successfully executed 16 radio-controlled commands, actuating elevator, aileron, and rudder and throttle controls during 25 minutes of radio-controlled flight. Despite the successes, an attempt at a fully unmanned flight was postponed for nearly a year.



C.B. Mirick, c. 1920s. American Institute of Electrical Engineers Washington Section (Photo: Harris & Ewing Studios, Washington, D.C.)



Albert Hoyt Taylor, first superintendent of NRL's Radio Division.

On September 15, 1924, following two flawless radio-controlled manned flights, Lt. Ballentine exited the test aircraft and was "replaced" with a bag of sand that equaled his weight distribution. The single, 150-horsepower, Hispano-Suiza engine was started and the pilotless plane taxied onto the Potomac River for its maiden unmanned flight.

After a successful departure, the plane was put through its paces for the duration of the 40-minute flight. Executing all but one of the 50 radio-transmitted commands (a right turn), the plane was safely returned to Dahlgren and guided to a ceremonious landing. For the first time in U.S. history, a pilotless aircraft had been flown from takeoff through full flight maneuvers and returned for landing solely by ground-based radio control. Encapsulated by the shroud of secrecy covering warfare research, and unbeknownst to the researchers at NRL and the Navy Bureau of Ordnance and Bureau of Engineering, the British had enjoyed a similar accomplishment just 12 days earlier.

Following the success of pilotless flight, the equipment was transferred to newer Vought built seaplanes, and testing resumed the following summer. With nearly 30 successful radio-controlled flights being conducted with a safety pilot onboard, an attempt to again fly fully unmanned was made in December 1925. Unfortunately, radio commands sent through the Baudot device led to "jerky" control inputs, resulting in the craft porpoising on takeoff, crashing, and eventually sinking. Although scientists at NRL were developing improved radio equipment and a less complex joystick type controller, interest in the program began to wane and the project eventually mothballed.

For nearly a decade, research involving pilotless aircraft at NRL remained dormant. The program was revived in the middle 1930s as the need arose to develop a more suitable and realistic aerial target to adequately train Navy anti-aircraft gunners. With aircraft design and development assigned to the Naval Bureau of Aeronautics and Bureau of Engineering, NRL was given the responsibility to develop the radio control system to fully operate aircraft control surfaces and throttle. In 1937, the NRL system was first used in remotely operated Navy target aircraft, or target drones, improving accuracy and revealing an additional need for an improved tracking and targeting system.

Today, unmanned aerial vehicles perform a wide range of missions and are used by all four branches of the military. They range from large vehicles that can carry offensive weapons to miniature systems that are light and compact enough to be carried in a soldier's backpack. The Naval Research Laboratory has been developing small UAV technologies and mission demonstrators since 1975. The modern, propeller-driven UAV complements current military and intelligence systems by performing missions that are too monotonous, dangerous, or expensive for existing manned platforms.

NRL continues to be at the forefront of UAV technology. In November 2009, NRL researchers, through sponsorship of the Office of Naval Research and with a team from Protonex Technology Corporation, the University of Hawaii, and HyperComp Engineering, demonstrated the Ion Tiger hydrogen fuel cell UAV. The craft shattered all previous endurance records performed by similar, propeller-driven, fossil fuel and battery-powered UAVs by completing an uninterrupted 26-hour flight carrying a five-pound payload (see the feature article in this issue of *Spectra*).

By Daniel Parry (NRL Office of Public Affairs).

Navy Researchers Apply Science to Fire Fighting

"Our mission is to preserve and enhance a strong technology base for the introduction of advanced damage control concepts to the fleet."

A fire aboard a Navy ship can quickly become a deadly cauldron. The grim reminders of this are the fires that took place aboard USS *Forrestal* in 1967 and USS *Enterprise* in 1969. In each case, burning jet fuel and multiple explosions of ordnance created a raging inferno that killed or injured hundreds of servicemen. At the Naval Research Laboratory (NRL), the Navy's lead laboratory for fire research, scientists are conducting cutting-edge investigations to ensure that sailors have the tools and training they need to protect themselves, their ships, and their submarines from the devastating effects of fire.

NRL's Navy Technology Center for Safety and Survivability tackles all aspects of fire — combustion, extinguishment, modeling and scaling, damage control, atmospheric hazards, and more. Research ranges from the most fundamental understanding of the chemical and electronic properties of materials, surfaces, and molecules; to numerical simulation of the growth, spread, and suppression of fires; to sensor development and data analysis; to full-scale test and evaluation of protection and suppression systems.

As Dr. Susan Rose-Pehrsson, Director of the Center explains, *"our mission is to preserve and enhance a strong technology base for the introduction of advanced damage control concepts to the Fleet."*

The Center operates specialized fire research facilities that include fully instrumented chambers with capacities up to 10,000 cubic feet; ship and submarine compartment mockups; and one of its most important and unique assets, a full-scale fire test ship, the ex–USS *Shadwell* (LSD 15), moored in Mobile, Alabama. NRL and Fleet personnel regularly set areas of the *Shadwell* aflame to conduct real-world fire testing, providing invaluable opportunities to experience and learn from a true fire and damage control environment. The *Shadwell* "concept" as developed and explained by Dr. Fred Williams, Senior Scientist and former Director of the Center, "*brings together the scientists, Fleet personnel, trainers, and systems commands in one place to show the transition of doctrine, tactics, and hardware into the Fleet."*


The ex-USS *Shadwell* (LSD 15) is regularly set ablaze for NRL's full-scale fire tests.

Two of NRL's recent advances in shipboard fire fighting research involve testing high expansion (hi-ex) foam systems for use on future ships, and finding halon alternatives for the new Ship-to-Shore Connector (SSC).

High Expansion Foam

NRL recently completed a series of full-scale tests on high expansion foam to assess its ability to extinguish fires in large-volume, mission-critical shipboard spaces such as hangar bays, well decks, and vehicle stowage areas. Hi-ex foam was pursued because of its tremendous "3D capability" — it rapidly expands to fill the volume of flammable spaces, flowing around obstructions and machinery to extinguish flames even in the confined and inaccessible spaces where fires can collect. This 3D capability means less need to send firefighters into those dangerous burning spaces. And hi-ex foam extinguishes the fire with less liquid solution than is typically delivered by deluge sprinkler systems — which means less water damage and less post-fire cleanup.

In the tests conducted aboard the *Shadwell*, NRL compared two hi-ex foam generation systems against a triple-threat fire composed of Class A combustible solids, Class B pooled fuel, and Class B running fuel. The two hi-ex systems were a traditional fan-type system requiring outside air to generate expanded foam, and an inside-air system using ceiling-mounted generators within the affected space. The inside-air system would be less expensive in a ship design, as it would not require external duct work, but historically, foam generators have not functioned well in enclosed, burning environments where only hot, fire-contaminated air is available.

The Navy researchers found that both hi-ex systems rapidly extinguished the test fires, and they consider hi-ex foam the best choice for fighting multiple-threat fires in obstructed compartments. Particularly important, they demonstrated in these tests that an inside-air foam system can be effective.

Due to the success of NRL's research and testing, high expansion foam systems will be used in the mission bay of the new Joint High Speed Vessel, and may be incorporated into other future ship designs as well.


98-megawatt fire set for hi-ex foam tests.

Halon Alternatives for the Ship-to-Shore Connector

NRL began research into replacement of halon in firefighting agents well before the 1989 *Montreal Protocol on Substances that Deplete the Ozone Layer* mandated a halt in the production of halons by 1994. By the 1990s, after laboratory and full-scale test programs, NRL identified both high-pressure water mist (1000 psi) and HFC-227ea (heptafluoropropane) as the best halon-free fire protection options for Navy applications. NRL developed the water mist system that is now in use aboard the LPD 17 San Antonio class of vessels.

In an ongoing program, NRL is identifying halon replacements for use on the SSC, a vessel the Navy is developing to replace the existing Landing Craft Air Cushion (LCAC), a high-speed, fully amphibious landing craft used to transport military personnel and equipment ship-to-shore. The Halon 1301 and Halon 1211 systems that currently protect the turbine engine enclosures, auxiliary power units, fuel bays, and cargo deck on the LCAC must be replaced with halon-free agents for the SSC. Also, since the SSC will be minimally manned, and weight will be a critical factor, firefighting agents and systems that offer low maintenance and low weight are essential.

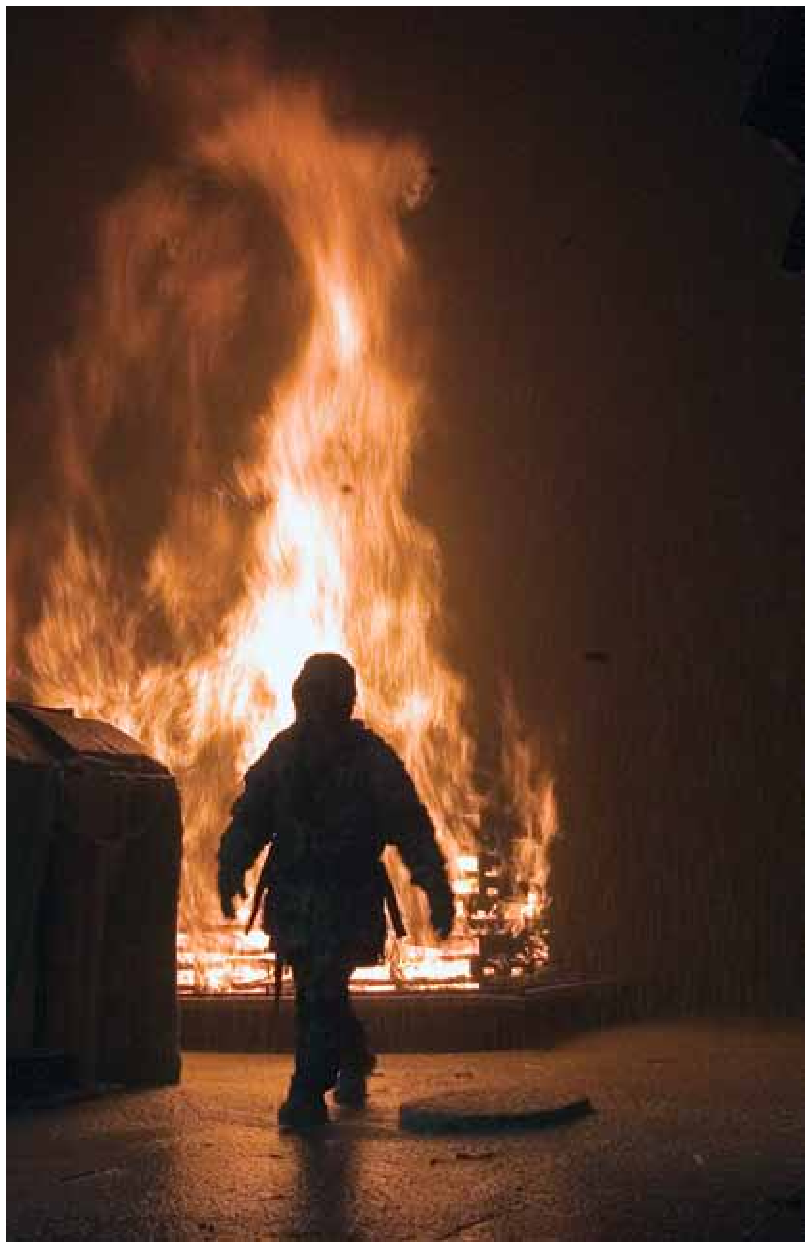
NRL researchers recently completed tests that successfully demonstrated the effectiveness of propelled extinguishing agent technology (PEAT) to protect many areas of the SSC. A PEAT system consists of a container holding extinguishing agent that is expelled rapidly when the system is activated by an electrical impulse or charge, using the same technology found in automobile air bags. In testing, PEAT solid particle aerosol units were able to extinguish all of the Class B pool and Class B spray fire threats.

NRL's success with the SSC halon replacement program is significant because PEAT is an effective technology remedy that provides many benefits:

- an environmentally friendly fire fighting agent (low Ozone Depletion Potential and Global Warming Potential, as defined by the Environmental Protection Agency),
- a module approach with sealed units (no moving parts, no pressurized containers, no pumps, and self-monitoring electric release),
- simple installation and minimal maintenance (no pipes to be installed),
- a 50 percent reduction in weight for the SSC application, and
- long shelf life (10 years minimum).

PEAT may soon be used in other Navy ship applications where a low-cost and low-weight fire protection system is desired.

NRL's fire research program continues to advance new concepts, materials, and doctrine in fire protection and damage control. While these are directed toward Navy problems, many have also had an impact in the civilian world, as noted in the following timeline of NRL fire research milestones.



NRL's Fire Research History Timeline

NRL has a long and rich history of fire research that has contributed greatly to saving lives and equipment in the Fleet.

1940s - NRL developed a protein foaming agent used to counter fuel fires, and potassium superoxide used as an oxygen source for Navy firefighter rebreathers.

1950s - NRL developed Purple-K powder (PKP) potassium carbonate firefighting agent, which gained use throughout the Navy and in U.S. municipal and industrial fire protection, and thereafter throughout the world.

1960s - NRL developed Aqueous Film Forming Foam (AFFF), which is now used by all Navy ships and submarines, all branches of the U.S. armed forces and NATO members, almost all U.S. fire departments, and many fire departments throughout the world.

1970s - The NRL-developed Twin Agent Unit (AFFF+PKP) was deployed to the Fleet.

1980s - NRL's FIRE I test bed, a 10,000-cubic-foot chamber, was dedicated to study submarine fires. One outcome was development of a new thermal hull insulation. The Navy deployed the NRL-developed Infrared Thermal Imager that allowed firefighters to see through smoke. The ex–USS *Shadwell* was commissioned as a full-scale fire test bed.

1990s - NRL data revised 90% of the Navy's firefighting doctrine. NRL adopted the halon alternative HFC-227ea and developed a fine water mist fire suppression system. NRL's water mist and smoke ejection systems were selected for the LPD 17 amphibious transport dock ship. NRL's Damage Control Automation for Reduced Manning (DC-ARM) program showed the way to performing damage control with significantly reduced manpower.

2000s - NRL developed sensor technology and data analysis for improved fire detection; the Network Model for real-time prediction of fire and smoke for ship design; the Smart Valve for autonomous fluid system isolation; the multi-sensory system (machine vision) for early detection of fire, flood, chem/bio, and other hazards; and alternative aqueous foam agents.

Contributors to this article include Donna McKinney (NRL Office of Public Affairs), with the assistance of Dr. Frederick W. Williams, Dr. Susan Rose-Pehrsson, and John P. Farley (NRL Navy Technology Center for Safety and Survivability).

Beautiful Defects: Looking Inside Rare Diamonds

The song says that "diamonds are a girl's best friend," but scientists at the Naval Research Laboratory are finding that diamonds are a researcher's best friend too. For more than 20 years, NRL has been involved in pioneering work involving chemical vapor deposition of diamond and the use of diamond materials in advanced technologies relevant to the Department of Defense; recently, the Lab has undertaken some new projects in diamond research.

Many of the properties of diamond necessary for technology applications (e.g., conductivity, hardness, optical properties) are impacted by defects and impurities present in the lattice. NRL has been complementing its studies of these defects and impurities in chemical vapor deposition diamond materials with studies of natural diamonds at the Smithsonian Institutuion.

In collaboration with the Smithsonian's National Museum of Natural History, NRL researchers are studying unique and historic natural colored diamonds to understand and characterize the defects and impurities that cause their different colors. Since late 2005, an NRL team led by Dr. James Butler of the Chemistry Division has examined several rare, natural colored diamonds that are part of the Smithsonian Collection or are on loan to the Smithsonian. These include the famous "Hope," "Blue Heart," and "Wittelsbach-Graff" blue diamonds and a collection of natural pink diamonds.

The Wittelsbach-Graff diamond (31.06 carat, left) and the Hope diamond (45.52 carat, right) apparently were not cut from the same crystal, even though they share several similarities, such as strong red phosphorescence (bottom). *(Photos by Chip Clark, Smithsonian)*

Hope Diamond and Wittelsbach-Graff Diamond

During 2005, NRL researchers Drs. James Butler, Sally Magana (National Research Council postdoctoral fellow), Jaime Freitas, and Paul Klein worked with the Smithsonian, Penn State University, and Ocean Optics to study the optical emission properties of the Hope diamond. This work, "Using Phosphorescence as a Fingerprint for the Hope and Other Blue Diamonds," was published in *Geology* 36, 83-86 (2008). In 2010, NRL is working with the Smithsonian and the Gemological Institute of America to study another famous blue diamond, the Wittelsbach-Graff diamond.

Both the Hope and the Wittelsbach-Graff diamonds are believed to have originated from the same region in India in the 17th century, have similar blue color, and have nearly identical red/orange phosphorescence when excited by ultraviolet light. Hence, it has been speculated that they might have originated from the same stone. The Wittelsbach-Graff diamond was last seen in public in 1958; then in 2008, diamond dealer Laurence Graff

The research team observing the ultraviolet/visible transmission spectrum of the Wittelsbach-Graff blue diamond. *(Photo by Chip Clark, Smithsonian)*

bought it at auction for 16.4 million GBP ($24.5 million U.S.). Graff had the stone cut and repolished, reducing it from a 35.5 carat stone to a 31 carat stone, compared to the Hope diamond which is 45.52 carats.

The research team studying the Wittelsbach-Graff diamond used a variety of spectroscopic and microscopic analyses to determine the extreme similarity of the gems, but also observed distinct differences in the dislocation and strain microstructure that suggest that the gems probably did not originate from the same rough stone.

The Wittelsbach-Graff is on display at the National Museum of Natural History from February to August 2010 along with the Hope diamond.

Pink Diamonds

NRL is also collaborating with the Smithsonian in an interdisciplinary effort to study pink diamonds, which are extremely rare, on a par with blue diamonds in rarity and value. Led by Drs. Jeff Post, Eloïse Gaillou, and Tim Rose of the National Museum of Natural History, NRL researchers Butler (Chemistry Division), Drs. Rhonda Stroud and Nabil Bassim (Materials Science and Technology Division), Dr. Alexander Zaitsev of the City University of New York, and Dr. Marc Fries of JPL/Cal Tech used spectroscopic and microanalytical tools to study the structure, defects, and impurities in a suite of natural pink diamonds.

A transmitted light photograph of a polished surface of a pink diamond. The pink lamellae ("graining") are approximately normal to the polished surface; the diamond between the lamellae is colorless.

Unlike most blue diamonds, in which the color is caused by an impurity (boron atoms), pink diamonds seem to derive their color from structural defects or a combination of structural and impurity related defects. While the researchers have not identified the exact structure of the defects causing the pink color, they have determined that it is contained in narrow, colored bands or lamellae in an otherwise clear matrix of diamond. Using a focused ion beam microscope, NRL researchers extracted cross-sections of the pink lamellae for detailed examination in a transmission electron microscope (TEM). TEM examination of the lattice structure, combined with spectroscopic analysis, suggest that the lamellae are the result of plastic deformation which occurred while the diamond was still in the Earth's mantle and before it was transported to the surface in ancient volcanic eruptions.

The team will continue its studies to characterize the diamonds to try to fully identify the nature of the color-forming defects. *"The pink lamellae are twin domains, with atoms arranged to mirror almost exactly those of the surrounding clear diamond. The real question is, what subtle shift in the atomic arrangement makes the twins pink but leaves the nearly identical sibling colorless? The sub-angstrom imaging capabilities of the latest generation of electron microscopes should tell us the answer,"* says Stroud.

"Understanding these unique colored natural diamonds provides knowledge useful to both technologists and gemologists," Butler explains. *"A better understanding of these defects and impurities (dopants) allows us to tailor the properties of diamond materials: from electrically insulating to semiconducting; from optically transparent to a variety of colors; or to provide the isolated quantum states for quantum cryptography or quantum computing."*

By Donna McKinney (NRL Office of Public Affairs).

NRL SCIENTIST Ho

CHRISTENING OF

THE FATHER OF ELECTRO

Susan Lorenzen Black christened the Navy's newest missile range instrumentation ship, named in her father's honor.

A prominent Naval Research Laboratory scientist and leader was honored on June 26, 2010, when the U.S. Naval Ship *Howard O. Lorenzen* (T-AGM 25) was christened in a formal ceremony at VT Halter Marine shipyard in Pascagoula, Mississippi. The new missile range instrumentation ship was christened by Mrs. Susan Lorenzen Black, the daughter of the late Howard Otto Lorenzen, an NRL electrical engineer who was instrumental in creating our nation's electronic intelligence (ELINT) capabilities.

In a career that spanned 33 years at NRL, Howard Lorenzen (1912–2000) became known as the "Father of Electronic Warfare" for his development of radio countermeasures concepts, techniques, and systems for military operational support. Lorenzen's research focused on developing electronic means to detect, locate, record, jam, and otherwise deceive enemy radar and other electronic locating equipment.

"Lorenzen understood and the Navy realized not only the value and relevance of detecting enemy radio and electronic transmissions, but that recording, analyzing, and deciphering these transmissions and developing intuitive countermeasures would prove to be integral and vital to the future of national security," said Pete Wilhelm, director of NRL's Naval Center for Space Technology.

Lorenzen worked at NRL from 1940 to 1973, starting as a radio engineer and later becoming superintendent of the Lab's new Electronic Warfare Division and then of the new Space Systems Division. One of his many notable achievements was his leadership of the Galactic Radiation and Background (GRAB) satellite program. GRAB I, launched in 1960, was the United States' first ELINT satellite, intercepting Soviet radar signals during the height of the Cold War. At that time, Lorenzen was already so renowned for his electronic countermeasures work that he was forbidden from attending the launch of GRAB I or follow-on missions,

NRL scientists Dr. Herbert Eppert (left), Superintendent of the Marine Geosciences Division, Peter Wilhelm (center), Director of the Naval Center for Space Technology, and Dr. Edward Franchi (right), Associate Director of Research for Ocean and Atmospheric Science and Technology, took part in the christening ceremonies of the USNS *Howard O. Lorenzen*.

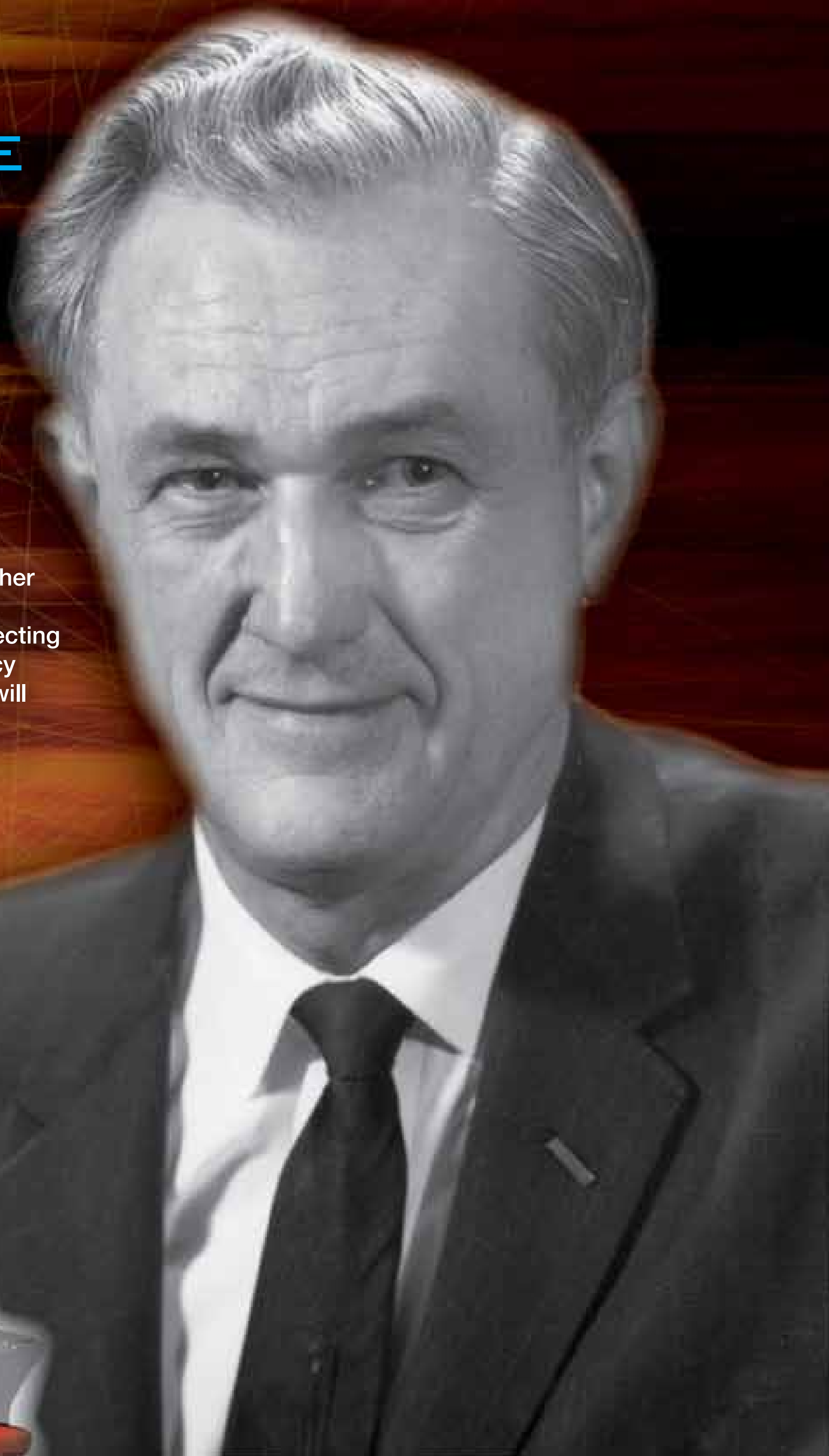
WARD OTTO LORENZEN COMMEMORATED IN USNS HOWARD O. LORENZEN

NIC WARFARE

for fear his presence might give away their classified ELINT mission.

USNS *Howard O. Lorenzen* is the second Navy ship to be named after an NRL scientist for contributions made to Naval and civilian scientific research; the other is USNS *Hayes*, launched in 1970 and named after underwater acoustics pioneer Harvey C. Hayes.

Operated by the Military Sealift Command, the 12,575-ton, 534-foot *Lorenzen* is equipped with a new dual-band phased array radar system and other advanced mission technology. The ship will be a platform for monitoring missile launches and collecting data that can be used to improve missile efficiency and accuracy. When the *Lorenzen* is launched, it will be used for the kind of electronic intelligence its namesake innovated.



Roger Easton, "Father of GPS," Inducted Into Inventors Hall of Fame

Visionary of Satellite Tracking, Timing, and Navigation Technologies

Joining the likes of world-renowned inventors Thomas Edison and Alexander Graham Bell, former Naval Research Laboratory scientist Roger L. Easton was inducted into the National Inventors Hall of Fame in a ceremony on March 31, 2010. Easton is widely recognized for his pioneering achievements in spacecraft tracking and time navigation (Easton's TIMATION) that were critical enabling technologies for the NAVSTAR Global Positioning System (GPS).

The award ceremony was hosted by Under Secretary of Commerce for Intellectual Property and Director of the United States Patent and Trademark Office, David Kappos, and was held at the Department of Commerce Herbert C. Hoover Auditorium in Washington, D.C. Easton was cited for inventing the TIMATION Satellite Navigation System, U.S. Patent 3,789,409 ("Navigation System Using Satellites and Passive Ranging Techniques," January 29, 1974).

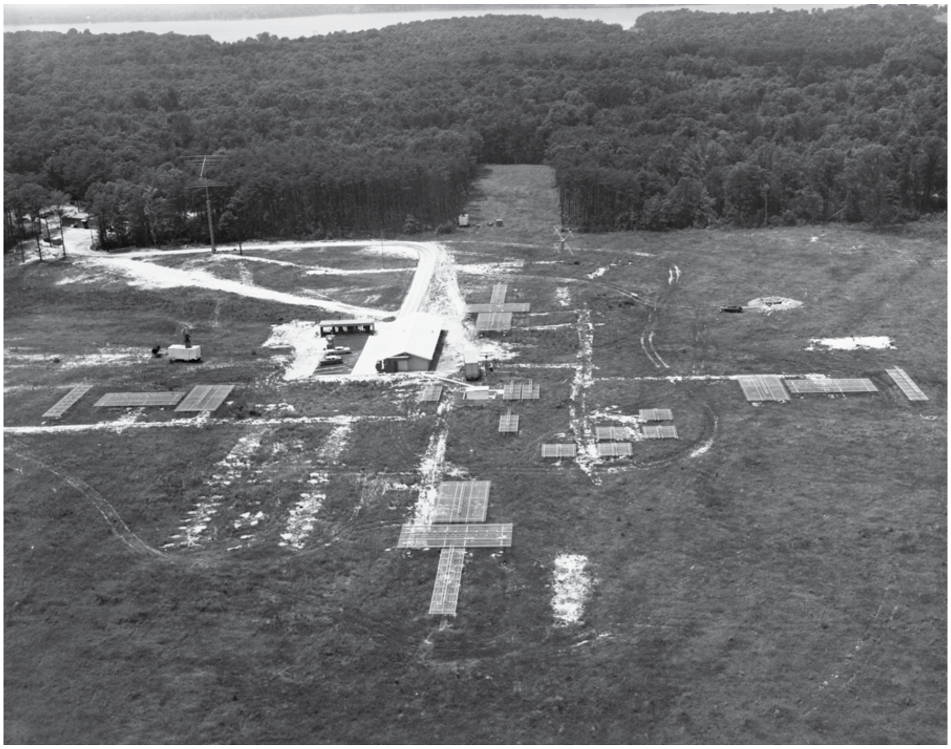
Easton developed and tested his revolutionary concept for a time-based satellite navigation system over a long career at NRL.

Taking the Guesswork Out of Satellite Tracking

Easton came to NRL in 1943 as a research physicist and began working on the development of radar beacons and blind landing systems at the Lab's Radio Division. In the 1950s, Easton collaborated with electrical engineer Milton Rosen to write NRL's Project Vanguard proposal for a scientific satellite program for the International Geophysical Year (IGY). The IGY was an unprecedented international effort to advance scientific studies of Earth;


Mr. Roger Easton (left) supervising the placement of the *Vanguard I* satellite atop the Vanguard launch vehicle, 1958.

it extended from July 1, 1957, through December 31, 1958. In 1955, the Eisenhower Administration selected NRL's Vanguard program to repre-



Blossom Point satellite tracking station, Maryland (ca. 1956). The MINITRACK system incorporated phase-comparison and angle-tracking techniques and used a series of fan-shaped, vertical antenna beams. The antennas are seen as rectangular objects on the field. As *Vanguard I* passed over each MINITRACK station, measurements of the angle and time allowed determination of the satellite's orbit.

sent the United States in the IGY and approved a plan to orbit a series of instrumented Earth satellites. Easton was one of the main scientists in the program.

NRL's Vanguard mission was to design, build, launch, and track a satellite carrying a scientific experiment. Easton not only helped to design the *Vanguard I* satellite (which launched March 17, 1958, and is still in orbit today), he and his colleagues also designed and built the first satellite tracking system. The system was called MINITRACK, because it minimized the weight and power requirement of the satellite transmitter, which only needed to transmit a signal of a few milliwatts due to the very high sensitivity of the MINITRACK interferometer antenna design.

Each MINITRACK ground station had pairs of interferometer antennas at right angles, with each measuring the angle to the transmitting satellite as it passed through its vertical "fan beam" antenna pattern. There were six such stations located approximately along the 75th meridian stretching down the east coast of the United States to the west coast of South America, with one other station near San Diego, California. This network of stations, each measuring the angle and time of passage overhead of the tiny, grapefruit-sized *Vanguard*, provided sufficient data to determine the precise orbit of the satellite.

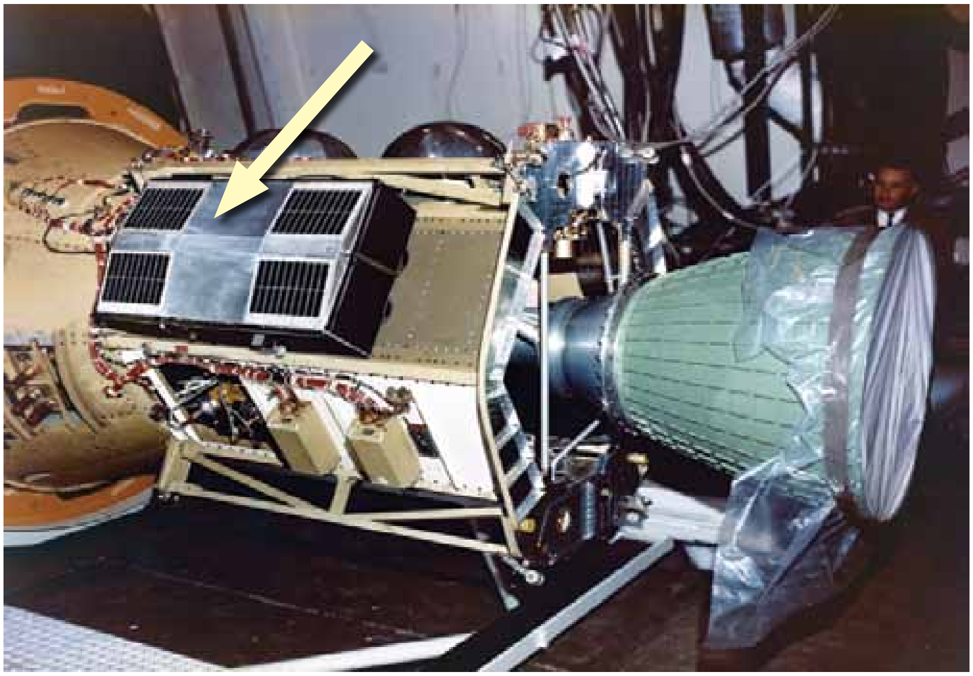
NAVSPASUR

When the Soviet Union launched *Sputnik* into orbit in October 1957, the United States could not track non-radiating satellites. Easton solved this problem by once again using interferometer antennas to actively follow unknown satellites orbiting Earth. Under his leadership, with sponsorship through the Department of Defense Advanced Research Projects Agency, now referred to as DARPA, this new tracking system became the Naval Space Surveillance System (NAVSPASUR). Commissioned as an operational command in 1961, NAVSPASUR was the world's first system to detect and track all types of Earth-orbiting objects — a system that contributed to America's national security and sense of well-being during the Cold War.

Long-time colleague of Easton and current Director of NRL's Naval Center for Space Technology, Peter Wilhelm recalls Easton's work: *"After seeing how well the very sensitive MINITRACK interferometer antenna field at Blossom Point, Maryland, detected and measured reflected 108-MHz radio frequency energy off the metallic shell of the Sputnik satellite, Roger quickly put together a proposal to build a new interferometer antenna system which, in a very short time, became the United States' most capable system for what we today call 'Space Situational Awareness' or SSA."*

"His leap in vision led to the United States' first satellite tracking network and his system of synchronized timing between spacecraft and user permitted 'passive ranging' which became the fundamental basis for GPS."

-- Pete Wilhelm
Director
NRL Naval Center for Space Technology



TIMATION I satellite (rectangular object) shown mounted on the side of its launch vehicle. This was the first satellite to demonstrate "passive ranging."

NAVSPASUR was a radar "fence" that stretched from California to Georgia along a "great circle" at 33 degrees. It consisted of nine stations: six receivers and three transmitters. The data from all six receivers was brought together at a central processing station in Dahlgren, Virginia, where the orbits of all objects passing through the fence, above a certain minimum radar cross section, were calculated and stored in a catalog.

"As the number of objects in orbit grew," added Wilhelm, *"it became apparent to Roger that by adding a 'second fence' south of the main fence, with an offset of about 480 miles, a 'one pass' solution could be provided to determine the object's orbit. Roger further improved the accuracy and utility of the data by adding ranging tones to the transmitted signal at the second fence. This, however, required that the receiving and transmitting sites, which were about 90 miles apart, had to be set precisely on the same time base. Maintaining the required accuracy turned out to be difficult to accomplish, which led Roger to the vision that the way to do this was to put very good clocks, probably atomic clocks, in satellites."*

NTS-2 satellite team: (standing, left to right) Dr. Bruce Faraday, Mr. Richard Statler, Mr. Guy Burke, and Mr. Roger Easton; (seated, left to right) Mr. Al Bartholomew, CDR Bill Huston, Mr. Red Woosley, Mr. Ron Beard, Mr. Woody Ewen, and Mr. Pete Wilhelm.

A Patent in Time

Easton conceived the idea of using satellite-carried precise atomic clocks for passive ranging. Starting in 1964, he conducted research, carried out space-based experiments, and published his findings that accurate, reliable, and instantaneous satellite navigation could be achieved with a combination of passive ranging, circular orbits, and a constellation of space-borne high-precision clocks synchronized to a master clock — the primary features of modern GPS.

His work exploiting space-based systems for geodesy, navigation, and timing laid the foundations for his visionary leap to the concept he dubbed TIMATION. Sponsored by the Naval Air Systems Command, Easton tested his concepts at NRL through the development and launch of four experimental satellites: TIMATION I (1967), TIMATION II (1969), TIMATION IIIA/Navigation Technology Satellite (NTS)-1 (1974), and TIMATION IV/NTS-2 (1977).

NTS-2, the first satellite to fly in the GPS 12-hour orbit and transmit GPS signals, flew the first cesium atomic frequency standard in space. Using time measurements from NTS-2, Easton experimentally verified Einstein's theory of relativity. A relativistic offset correction that he applied is still in use by every satellite in the GPS constellation. While initially designed for use by the military, GPS has been adapted for civilian use from commercial airline navigation to portable handheld and wrist-worn devices. GPS today is a constellation of Earth-orbiting satellites providing precise navigation and timing data to military and civilian end-users around the globe.

A Legacy

Easton retired from NRL and federal service in 1980, going into public service in his home state of New Hampshire, and later serving as a consultant to NRL to assess industry proposals for upgrading the Naval Space Surveillance System and to explore his concept for improving GPS geolocational accuracy.

Easton has been awarded 11 patents and has received several major awards and honors for his accomplishments. In 1978, he received The Institute of Navigation's Colonel Thomas L. Thurlow Award recognizing outstanding contributions to the science of navigation. In 1991, the Naval Space Surveillance Center established the Roger L. Easton Science and Engineering Award to mark the 30th anniversary of the Naval Space Surveillance System. The National Aeronautic Association presented its 1992 Robert J. Collier Trophy to the GPS Team composed of NRL, the U.S. Air Force, Aerospace Corp., Rockwell International, and IBM Federal Systems "for the most significant development for safe and efficient navigation and surveillance of air and spacecraft since the introduction of radio navigation 50 years ago."

In 1997, Easton and Bradford W. Parkinson were each awarded the American Philosophical Society's Magellanic Premium for Navigation "for essential contributions to creating the Global Positioning System, thereby making the tools for precision navigation available to everyone." Most recently, Easton was awarded the 2004 National Medal of Technology by President George W. Bush "for his extensive pioneering achievements in spacecraft tracking, navigation, and timing technology that led to the development of the NAVSTAR Global Positioning System."

Roger L. Easton joins 15 other new inductees into the National Inventors Hall of Fame. The National Inventors Hall of Fame honors the women and men responsible for the great technological advances that make human, social, and economic progress possible. Each year, the selection committee selects inventors for induction from those nominated by peers and the public for contribution to the nation's welfare and progress of science and useful arts. The selection committee includes representatives from leading national scientific and technical organizations. Including this year's honorees, 421 inventors have been inducted into the National Inventors Hall of Fame since its formation in 1973.

President George W. Bush awarded the 2004 National Medal of Technology to Roger Easton.

Edward Gray, President of the National Inventors Hall of Fame Board of Directors, Roger Easton, and David Kappos, Director of the U.S. Patent and Trademark Office, at the National Inventors Hall of Fame induction ceremony on March 31, 2010.

Contributors to this article include Daniel Parry (NRL Office of Public Affairs); Peter Wilhelm (Director, NRL Naval Center for Space Technology); and Roger Easton.

NRL VOTED AS A TOP PLACE TO WORK FOR POSTDOCS

TheScientist 2010 BEST PLACES TO WORK POSTDOCS

In a survey conducted by *The Scientist* magazine (results published in the March 2010 issue), the Naval Research Laboratory ranked 16th among 90 U.S. and international institutions as the best places to work for Postdocs.

During September through November 2009, email invitations were sent to readers of *The Scientist* and registered users on *The Scientist* web site who were identified as non-tenured life scientists working in academia or other non-commercial research institutions. Postdocs were asked to assess their working environment based on such criteria as quality of training and mentoring, value of Postdoc experience, career development opportunities, and funding.

Listed as two of NRL's biggest strengths were compensation and equity. The 16th place ranking positions NRL above other renowned government organizations like the National Institutes of Health and the National Institute of Standards and Technology.

NRL Begins Southeast Asia Study of Aerosols Linked to Global Warming

NRL's Marine Meteorology Division has deployed the Mobile Atmosphere, Aerosol, and Radiation Characterization Observatory (MAARCO) to the National University of Singapore to begin the first comprehensive radiation and aerosol assessment in the Maritime Continent region. NRL is leading the effort to investigate ways in which to infer larger aerosol and visibility features from limited data sets, and to analyze the aerosol physical interactions and processes to aid numerical aerosol and weather predictions.

The Marine Meteorology Division, located in Monterey, California, has specifically designed and developed the unique MAARCO to be a rugged, easily transportable, flexible, and comprehensive suite of instruments to make surface measurements of the radiometric and meteorological properties of the atmosphere, the microphysical and compositional properties of aerosols, and the vertical distribution of aerosols and clouds. The instrumentation suite includes a LIDAR (light detection and ranging) unit, a Sun photometer, radiometers, particle probes, filter samplers, and impactors, as well as a host of weather instruments.

MAARCO is a transportable climate-controlled laboratory containing scientific instrumentation for measuring atmospheric aerosols, trace gases, chemistry, radiative properties, cloud structure, and meteorology.

The impact of biomass burning and pollution on the Maritime Continent is of considerable concern to global climate change researchers. The deployment of MAARCO is part of the overarching 7 Southeast Asian Studies (7SEAS) program — a comprehensive interdisciplinary atmospheric sciences program to study the interactions of pollution and smoke with regional meteorology, air quality, land surface science, and oceanography.

"The extreme cloud cover and complicated environment of the Maritime Continent allows for very few satellite observations of pollution and smoke to be properly ingested in the models," said Dr. Simon Chang, superintendent of the Marine Meteorology Division. "Field investigations will help researchers develop methods to make the best use of the limited data available and yield insight on how to constrain aerosol optical properties in models and satellite retrievals."

Navy interest lies in aerosol observability and numerical prediction issues, and in particular, aerosol radiative impacts. NRL developed many of the "world's firsts" of aerosol and pollution forecasting. NRL developed the first operational aerosol prediction system (NRL Aerosol Analysis and Prediction System, NAAPS) as well as the world's first operational aerosol data assimilation system which uses NASA satellite measurements to track pollution, dust, and smoke (the Navy Variational Analysis Data Assimilation System–Aerosol Optical Depth, NAVDAS-AOD).

International Expedition Investigates Climate Change and Alternative Fuels in the Arctic

NRL organized and led the MITAS-1 international research expedition aboard the USCGC *Polar Sea* in the Beaufort Sea, September 15–26, 2009. *(Photo: U.S. Coast Guard.)*

Scientists from the Naval Research Laboratory's Marine Biogeochemistry section and Geology and Geophysics section organized and led an international team on a recent expedition to study methane hydrates in the Beaufort Sea, Alaska. The 12-day expedition in September 2009 was called Methane In The Arctic Shelf and Slope (MITAS-1).

The expedition is part of an international collaboration to understand methane hydrates as both a potential new energy source and a potential contributor to global climate cycles.

Methane hydrates, or gas hydrates, are frozen mixtures of water and hydrocarbon gas (mostly methane), with the gas trapped in a cage-like molecular structure formed by the ice. The hydrates form in specific zones of low temperature and high pressure, and are found embedded in ocean sediments along the world's continental margins and in Arctic permafrost.

Methane hydrates are considered a promising new energy source for the future, if the trapped methane gas can be extracted and used as fuel. Not only is the global reservoir of methane vast, but methane gas is a relatively clean-burning fuel, producing significantly less carbon dioxide than the combustion of oil or coal.

But all that methane contained in the Earth's gas hydrate reservoir is also problematic, as methane is a potent greenhouse gas. It is feared that even a small fraction of methane released into the atmosphere during gas hydrate melting — a result of ocean warming, geothermal anomalies, or tapping the resource for energy needs — may lead to an amplification of global warming. This warming could, in turn, trigger further methane release in a destructive cycle. Some scientists fear that accelerated, natural thawing of permafrost is already causing destabilization of the hydrates.

Therefore, understanding the formation, location, extent, stability, and chemical characteristics of the world's methane hydrate deposits has become a priority for many nations.

The MITAS-1 team. Chief scientist Richard Coffin (NRL Marine Biogeochemistry) and co-chief scientists Warren Wood (NRL Geology and Geophysics), Jens Greinert (Royal Netherlands Institute for Sea Research), and Kelly Rose (Department of Energy–National Energy Technology Laboratory) led a team of 32 university and government scientists from the United States, Netherlands, Belgium, and Germany. Other NRL scientists included Leila Hamdan, Joseph Smith, Allen Reed, Rebecca Plummer, and Curt Millholland.

The MITAS-1 expedition focused on gathering data to measure "fluxes" or changes in the concentration of methane within and across the Beaufort shelf. *"The objective of the sampling is to help understand methane sources and cycling in the shallow sediment and water column, and the subsequent flux into the atmosphere,"* said NRL's Dr. Richard Coffin, MITAS-1 chief scientist.

Using the U.S. Coast Guard Cutter *Polar Sea* as a research platform, the team surveyed and sampled three cross-shelf transects off Alaska's North Slope, at Hammerhead, Thetis Island, and Halkett. The team conducted 34 conductivity-temperature-depth (CTD) water column casts and collected sediment samples from 14 piston cores, 3 vibrocores, and 20 multicores. Sites selected for the study were based on a review of pre-existing seismic data, with specific sample locations decided onboard through collection of sub-bottom profiler data.

In addition to onboard geochemical, physical property, and acoustic analyses of the sediment and water samples, post-cruise analyses are further studying geochemical, microbiological, isotope, and sedimentological properties.

The wealth of data collected on this cruise will establish benchmark measurements with which to evaluate future methane behavior in this region. MITAS-1 is the first step in a more thorough evaluation of the distributions and concentrations of methane and methane hydrates in the Arctic permafrost and oceans. *"Our project is intended to initiate a long-term collaboration in future expeditions to the Beaufort Sea and other regions of the Arctic Ocean,"* said Coffin.

The expedition was supported by NRL, the Office of Naval Research, the U.S. Department of Energy, the Royal Netherlands Institute for Sea Research (NIOZ), the French Research Institute for Exploitation of the Sea (IFREMER), and the German Leibniz Institute of Marine Sciences (IFM-Geomar). Future expeditions will also include scientists from Scotland's Herriot-Watt University, Norway's University of Bergen, and GNS Science of New Zealand.

NRL has a well-established methane hydrate research program, developed over some 30 years. NRL scientists have expertise in geoacoustical data acquisition and interpretation to predict hydrate locations; onboard analysis of sediment and porewater samples; field and laboratory analysis of hydrate structure and content; isotope analysis (^{13}C, ^{14}C, ^{18}O, deuterium) to help differentiate between thermogenic and biogenic gas sources and to track cycling; and analysis of microbial community diversity. NRL has led or taken part in field expeditions all over the world, including in Chile, Canada, New Zealand, and the United States, and has co-sponsored several international conferences focused on methane hydrate research and development.

In addition to characterizing methane hydrates as an energy resource and contributor to climate change, NRL is also researching

- hydrate-related seafloor instabilities that can lead to slope failures that could adversely impact Navy systems;
- the impact of hydrates on undersea navigation and geoacoustic anomalies; and
- the potential for using methane hydrates *in situ* to power Navy systems (such as bottom-mounted sensors) or even to fuel unmanned underwater vehicles.

HICO™–RAIDS Team Honored with Rotary National Award for Space Achievement

The picture shows HREP's docking position to the JEM-EF. The RAIDS sensor, wrapped in yellow thermal blankets, is pointing to the lower left corner of the picture. The big round feature on the top is the grapple fixture for ISS' maneuverable arm. The black round hole next to this fixture is the baffle for the star tracker. The HICO™ sensor, enclosed by the HREP structure, is located to the right of RAIDS.

Naval Research Laboratory researchers who designed and built the HICO™–RAIDS Experiment Payload (HREP) have been honored with the Rotary National Award for Space Achievement Stellar Team Award. HREP launched on September 10, 2009, aboard the inaugural flight of the Japanese Aerospace Exploration Agency (JAXA) H-II Transfer Vehicle unmanned resupply ship under the auspices of the DoD Space Test Program (STP). Dr. Davidson Chen led NRL's HREP team.

The nonprofit Rotary National Award for Space Achievement Foundation was established by the Space Center Rotary Club of Houston in 1985 to recognize outstanding achievements in space and create greater public awareness of the benefits of space exploration. David Hess, director of the DoD Human Spaceflight Payloads Office of the DoD STP, and Dr. Perry Ballard, chief engineer for the DoD Human Spaceflight Payloads Office, accepted the award on behalf of the HICO™-RAIDS team April 30, 2010.

HREP was the first U.S. pathfinder launched aboard the Japanese H-IIB rocket, as well as the first to be both deployed and operated from the Japanese Experiment Module–External Facility (JEM-EF) on the International Space Station (ISS). Following docking to the ISS, robotic payload installation, and initial testing, HREP entered the normal science operations phase of its unique mission on October 19, 2009.

HREP provides all attitude knowledge, command and control, data handling, and structural support to the Hyperspectral Imager for the Coastal Ocean (HICO™) and Remote Atmospheric and Ionospheric Detection System (RAIDS) hyperspectral sensors. HICO™ is an Office of Naval Research (ONR) Innovative Naval Prototype program, with NRL's Dr. Michael Corson as the principal investigator. NRL's Dr. Scott Budzien is the RAIDS principal investigator. The DoD STP team, the NASA International Space Station Program, and ONR jointly coordinated the international effort that ultimately produced the first major Earth observing experiment conducted outside of ISS confines.

Led by Ballard, the international HREP team included the Department of State, NASA, JAXA, NRL, the Aerospace Corporation, ONR, and the DoD STP. This international integration effort required communication, coordination, cooperation, and incredible focus and dedication.

The result of this teamwork across the world is the deployment of two innovative experiments that provide high-quality and real-time monitoring of space weather and the coastal ocean environment. HICO™ images coastal zones in great detail, providing information critical to the day-to-day operations of the Navy. It is the first maritime hyperspectral imager in space. RAIDS images the horizon and above, collecting data on the composition and temperature of Earth's atmosphere. It is expected to provide the most comprehensive survey of the ionosphere and thermosphere in more than 20 years.

NRL's TEPCE Spacecraft Undergoes Successful Deployment Test

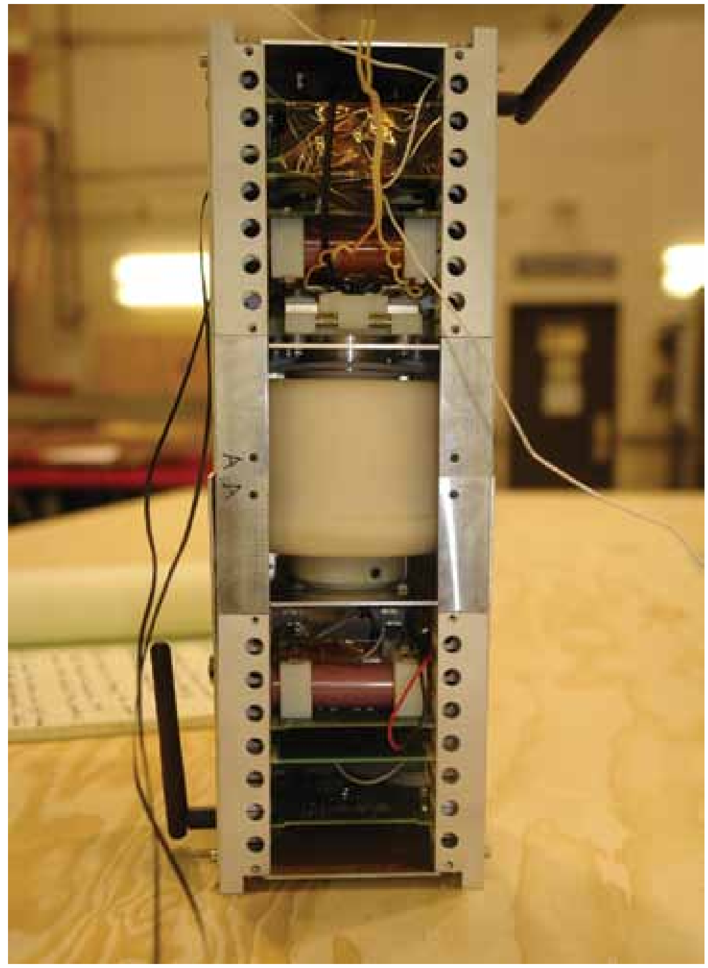
The Naval Research Laboratory's Tether Electrodynamics Propulsion CubeSat Experiment (TEPCE) underwent successful deployment tests on March 19 and March 23, 2010.

TEPCE is a tethered spacecraft being built by NRL to demonstrate electrodynamic propulsion in space. Electrodynamic propulsion holds the promise of limitless propulsion for maneuvering spacecraft without using expendable fuel. The spacecraft, in its orbital configuration, will consist of two CubeSat end masses attached to the end of 1 kilometer of electrically conducting tether.

Electrodynamic propulsion works on electromagnetic principles similar to an electric motor. The magnetic field in an electric motor attracts an electric current that flows through the windings of the armature, causing the armature to spin. In space, the Earth has a naturally occurring magnetic field and for TEPCE, the tether wire serves the purpose of the armature. By inducing an electric current to flow along the tether, a mutual attraction between the Earth's magnetic field and the tether will occur. This electromagnetic attraction can propel TEPCE to higher altitudes or can change the orientation of its orbit.

TEPCE during free fall deployment test, in a nearly vertical orientation. Rate gyros proved that sidewise rotations will not be a problem during deployment in space.

NRL researchers conducted the deployment tests in the Naval Center for Space Technology's high bay facilities at NRL. The tests exercised a spring deployment mechanism, called a stacer, which pushes the two CubeSats apart at a relative velocity of 4 meters per second. The tests were conducted in free fall that simulated the weightlessness of space. The CubeSats were instrumented with angular rate gyros and accelerometers that measured rotations and accelerations.



The integrated TEPCE spacecraft prior to deployment tests. The end masses are designed to be nearly identical. Visible in this picture are the batteries, partially complete electronics boards, and antennas to the radio receivers. The white cylinder in the middle eventually will house the tether.

The TEPCE deployment tests determined the effectiveness of the stacer mechanism to produce the required separation velocity while holding tip-off rotations to an acceptable level. *"The deployment experiment was a milestone in the development of the first tethered spacecraft to demonstrate electrodynamic thrusting for orbit maneuvers using energy derived from the sun instead of from expendable fuel,"* explains NRL's Dr. Shannon Coffey, TEPCE program manager.

The 6th Annual CanSat Competition co-sponsored by the Naval Research Laboratory's Naval Center for Space Technology, the American Astronautical Society, American Institute of Aeronautics and Astronautics, NASA Jet Propulsion Laboratory, NASA Goddard Space Flight Center, Ball Aerospace and Technologies Corporation, Praxis, Inc., and Dassault Systèmes SolidWorks Corporation was held in Amarillo, Texas, June 11-13, 2010.

The competition was created to provide a unique opportunity for teams to design and build a satellite that fits inside a soda can to meet a mission specified by the competition.

The competition is available to undergraduate and graduate students at universities and colleges in the United States, Canada, Mexico, and Europe and allows teams to design and build a space-type system according to the specifications released by the competition organizing committee. Teams then compete against each at the end of two semesters to determine the winners.

Although similar competitions exist for other fields of engineering (robots, radio-control airplanes, racing cars, etc.), most space-related competitions are paper design competitions. While these are worthwhile, they do not give students the satisfaction of being involved with the end-to-end life cycle of a complex engineering project, from conceptual design through integration, test, and actual operation of the system, and concluding with a post-mission summary and debrief. This competition fulfills that need.

Mission

The 2010 mission was to launch an autonomous CanSat carrying one large raw hen's egg intact for the entire duration from launch to landing. The descent control system could not use a parachute, para-foil, or any similar device. During the flight and descent, data was to be transmitted once every five seconds to a relay balloon station. The CanSat had to land without damaging the egg.

To learn more about this exciting and challenging competition, please visit the CanSat Web site:

http://www.CanSatcompetition.com/Main.html

SCIENCE TECHNOLOGY ENGINEERING MATHEMATICS

NAVAL RESEARCH LABORATORY

STEM PROGRAMS

NRL's student employment programs provide college and graduate students with opportunities to gain work experience while pursuing their educational goals. Students get exposure to career opportunities, learn valuable skills, and interact with professionals in the work environment. Positions are available in scientific and support fields. An applicant must be at least 16 years of age. U.S. citizenship required.

Student Temporary Employment Program (STEP)

Opportunities:
- STEP appointments last for one year and may be extended. Students can work year-round or during Summer, Winter, and Spring breaks.

Requirements:
- Attendance at an accredited educational institution on at least a half-time basis.
- Applications are accepted year-round.

Benefits:
- 4 hours annual leave and 4 hours sick leave each pay period for those with a prescribed tour of duty and an appointment of at least 90 days.
- After one year of service, students can purchase health insurance at the full premium.

Summer Employment Program (SEP)

Opportunities:
- SEP appointments can start as early as mid-May and must end by 30 September.

Requirements:
- Attendance at an accredited educational institution on at least a half-time basis.
- Competition for summer employment is extremely keen and candidates are given priority consideration based on demonstrated academic achievement and applicable work experience.
- Applications are accepted from mid-December through the second Friday in February.

Benefits:
- 4 hours annual leave and 4 hours sick leave each pay period for those with a prescribed tour of duty and an appointment of at least 90 days.

For more information and application instructions, visit:

http://hroffice.nrl.navy.mil/student/student_public.asp

(202) 767-3031

Student Career Experience Program (SCEP)

Opportunities:
- Students can work year-round or during Summer, Winter, and Spring breaks.

Requirements:
- Attendance at an accredited educational institution on at least a half-time basis.
- Enrollment in the educational institution's co-op program upon selection.
- Must maintain a 2.5 GPA on a 4.0 GPA scale.
- Students must be able to complete 640 hours of work under the program before completion of their degree program requirements.
- If tuition is paid by NRL, a continued service agreement must be signed.
- Applications are accepted year-round.

Benefits:
- 4 hours annual leave and 4 hours sick leave each pay period.
- Tuition and enrollment fees and other costs may be paid.
- Eligible for health and life insurance.
- Parallel or alternating work schedules.
- Eligible for conversion to permanent employment after graduation.

Naval Research Enterprise Intern Program (NREIP)

Opportunities:
- The NREIP provides an opportunity for students to participate in research at a Department of the Navy (DoN) laboratory during the summer. Internship has a duration of ten weeks.

Requirements:
- Applications must be completed online at http://nreip.asee.org. Please access the website for the application deadline.
- Attendance at a qualifying university. List of universities can be found at http://nreip.asee.org.
- Must be a Junior, Senior, or graduate student. Students can participate in the summer between their Sophomore and Junior years.

Benefits:
- Undergraduate students receive a stipend of $5,500 and graduate students receive $6,500.

NRL ON THE ROAD

NRL's Exhibit Program showcases a broad spectrum of NRL's technologies and achievements at specialized events and conferences nationally and internationally. The goal is to seek diverse and non-traditional audiences and excite visitors with interactive displays, models, artifacts, presentations, and participatory demonstrations.

SCHEDULE

ASNE Fleet Maintenance and Modernization Symposium	September 14-15, 2010	Virginia Beach, VA
USSTRATCOM Space Symposium	November 2-3, 2010	Omaha, NE
IEEE Nuclear Science Symposium	November 2-4, 2010	Knoxville, TN
Navy S&T Partnership Conference	November 8-10, 2010	Crystal City, VA
I/ITSEC 2010	Nov. 30 - Dec. 3, 2010	Orlando, FL
American Geophysical Union	December 13-17, 2010	San Francisco, CA
SPIE Photonics West 2011	January 22-27, 2011	San Francisco, CA
Information Assurance Expo 2011	TBD	
12th Annual Technologies for Critical Incident Preparedness	TBD	
Mission Planning Users' Conference (Builder)	TBD	
National Space Symposium	April 11-14, 2011	Colorado Springs, CO
Nanomaterials for Defense Applications	TBD	
Navy League – Sea Air Space	April 11-13, 2011	National Harbor, MD
8th Annual Team America Rocketry Challenge – National Finals	TBD	Great Meadows, The Plains, VA
Photovoltaic Specialists Conference	June 19-24, 2011	Seattle, WA
Nanotech Conference and Expo	TBD	
AUVSI	August 16-19, 2011	Washington, DC

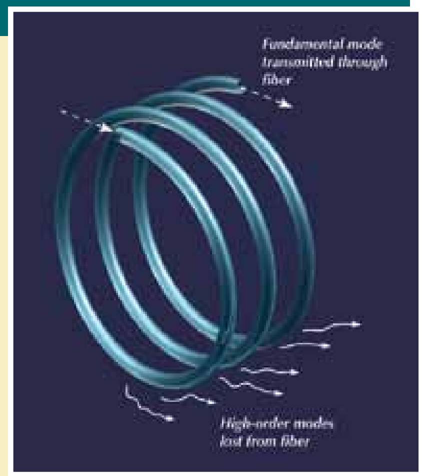
NRL's Technology Transfer Office (TTO) facilitates the implementation of NRL's innovative technologies in products and services to benefit the public. Detailed here are three recently commercialized technologies.

TRANSPARENT SPINEL CERAMIC

Material scientists at NRL developed a novel process to produce transparent spinel ceramic of superior strength and clarity for use in windows, protective armor, and numerous other applications. This patented processing method and its spinel ceramic product together represent notable advances over traditional processing methods and transparent materials in terms of scalability, production rates, performance, durability, and cost-effectiveness. Anticipated military applications range from personnel protective items like face shields, to explosive-resistant windows in aircraft, landcraft, and submarines, to high-energy laser systems. This technology has been licensed to MER Corporation of Tucson, AZ. Commercial uses appear nearly limitless, given the ubiquity of consumer electronics utilizing rugged transparent materials as, for example, display windows. Reduced manufacturing costs and improved performance assure that the NRL-patented spinel ceramic process could reshape industry technologies and product standards, with potential to capture a multi-billion-dollar share of the global market.

HELICAL FIBER AMPLIFER

Physicists at NRL and Sandia National Laboratories revolutionized fiber laser technology when they discovered that coiling laser fibers in precise dimensions filters out undesirable light modes, thereby making high-power fiber lasers possible. This inventive solution resolved the power limitations that had stymied the industry since fiber lasers were first developed in 1963, while preserving high beam-quality output. Helical fiber amplifiers now allow production of high-power fiber lasers that are more cost-effective, rugged, and compact than other types of lasers. Through licensing to Nufern of East Granby, CT; nLight Photonics Corporation of Vancouver, WA; and IMRA America, Inc., of Ann Arbor, MI, products embodying this technology will significantly affect industries like telecommunications, materials processing, and remote sensing. Applications range across the private and public sectors from real-time contaminant sensing and precision circuitry manufacture to secure high-bandwidth communications.



RESEQUENCING PATHOGEN MICROARRAY

NRL's Resequencing Pathogen Microarray (RPM) technology is a microbial pathogen identification assay that provides powerful biosurveillance capability in the control of infectious disease. Expertise in biology, engineering, and computer science were combined to create a rapid diagnostic that determines the genetic profiles of bacterial and viral pathogens in clinical samples like blood and nasal swabs. Genetic profiles are used to identify the pathogens, and these identities are then validated by comparison against on-line genetic databases. RPM technology offers several advances over similar technologies — same-day results, simultaneous detection of hundreds of pathogens in a single sample, and definitive identification down to strain or serotype levels. Through licensing to TessArae LLC of Potomac Falls, VA, products such as diagnostic kits that screen for avian influenza virus, Ebola virus, and infectious agents that might be used in bioterrorism are already available to customers. NRL's technology is pending FDA approval for medical use and is expected to play a significant role in disease surveillance in the future.

NRL-SSC Microbiologist Returns from Haiti

LCDR Matthew Doan, a microbiologist at Naval Research Laboratory–Stennis Space Center (NRL-SSC), recently returned from a 10-week deployment to Port au Prince, Haiti, as part of Operation Unified Response.

Doan, who is assigned to NRL's Marine Geosciences Division, volunteered to deploy to the region after learning of a need for a microbiologist in a Navy Forward Deployable Preventive Medicine Unit (FDPMU) from the Navy Environmental and Preventive Medicine Unit No. 2 (NEPMU2) located in Norfolk, Virginia.

"I knew everyone in the unit from previous deployments or training exercises," said Doan, *"So it was an easy decision to make."*

In addition to Doan, the 13-member team consisted of an environmental health officer, industrial hygiene officer, preventive medicine officer, entomologist, laboratory technician, general hospital corpsman, and six preventive medicine technicians.

Berthed less than a mile from the Port au Prince airport, the team was tasked with providing occupational and environmental risk surveillance (OERS) for Dept. of Defense personnel in camps around the island. The team ensured the health of DoD personnel who are providing valuable humanitarian assistance in the Haitian community.

Members of the Naval Environmental Preventative Medicine Unit in Haiti (LCDR Doan is pictured third from the right).

To prevent the spread of disease, the team sampled water, air and soil for potential health hazards and countered risks with various forms of preventive treatment. One major source of concern for the team was the ever-present mosquitoes and, thus, the possible spread of malaria and other vector-borne diseases among DoD personnel.

"The entomologist stayed busy responding to calls: spraying and putting out bait," said Doan. *"He was the face of the effort, the P.R. guy for what we were doing as a team."*

Despite the entomologist's best efforts and access to anti-malarial drugs, some DoD personnel still contracted malaria. When malaria was the expected cause of a person's illness, Doan was called to confirm the diagnosis by identifying the parasite.

He used the confirmed cases to stress to other sailors and soldiers the importance of using mosquito netting, taking their prescribed daily anti-malarial medication, and ensuring their uniforms were treated with DEET.

"Teaching is a form of preventive medicine," said Doan. In addition to teaching DoD personnel to prevent disease and injury, he also trained other medical and laboratory personnel in identifying diseases. When he deployed to the area in January, he brought microscopes, stains and other lab supplies to conduct his fieldwork. Prior to leaving Haiti, he trained Army medical technicians to use them to identify the presence of malaria.

"I saw things I will never forget," said Doan. *"I am thankful I went. It was rewarding work."*

On April 2, the deputy commander of Operation Unified Response said the U.S. military will continue to support the work of Haiti's government and international agencies after the task force is deactivated at the end of May. At its peak, some 20,000 U.S. servicemembers were involved in the mission. A phased withdrawal has reduced that number to 2,400.

THOMAS EDISON'S VISION OF NRL

February 11, 2010, marked Thomas Edison's 163rd birthday. In celebration, NRL looks back at Edison's idea for creating a government research laboratory during a time when Americans were worried about the first World War raging in Europe.

In an interview published Sunday, May 30, 1915, in the *New York Times Magazine*, Edison presented his case as to why the government should look to science as a necessity:

"...the Government should maintain a great research laboratory, jointly, under military and naval and civilian control. In this could be developed the continually increasing possibilities of great guns, the minutiae of new explosives, all the technique of military and naval progression, without any vast expense. When the time came, if it ever did, we could take advantage of the knowledge gained through this research work and quickly manufacture in large quantities the very latest and most efficient instruments of warfare..."

Upon reading Edison's public comments, Secretary of the Navy Josephus Daniels contacted Edison and enlisted his support on July 7, 1915. This lives on as a seminal moment for NRL, when Edison accepted Daniels' offer for him to head the Naval Consulting Board as an advisor to the Navy on science and technology. The Board made plans to create a modern research facility for the Navy that would embody Edison's vision. In 1916, Congress allocated $1.5 million to build the facility, but construction was postponed until 1920 when wartime delays and disagreements among members of the Board ended.

The original location of the laboratory was to be in Annapolis, Maryland, but Edison believed the better site to be Sandy Hook, New Jersey. The present site, on the Potomac River and just within the southern corner of the District of Columbia, became the compromise location. The committee favored the laboratory being located on tidewater with enough depth to allow a sizable ship to dock. With the Washington, D.C., site selected, the Naval Experimental and Research Laboratory (today called the Naval Research Laboratory) was completed in 1923. Radio and Sound were the Laboratory's two original research divisions, establishing themselves in the fields of high-frequency radio and underwater propagation.

These divisions produced communications equipment, direction-finding devices, sonar sets, and what is often thought to be the most significant accomplishment of all, the first practical radar equipment built in the United States. Over the years, the Laboratory accomplished its goal of becoming a broadly based research facility: the original Radio and Sound Divisions were soon followed by Heat & Light, Physical Metallurgy, and Chemistry, and then others as the Lab has continued to evolve.

Because of Edison's vision, throughout the years, thousands of researchers at NRL have benefited the country with their ideas for improving the capabilities of U.S. warfighters and answering the needs of the Navy and the Nation. Today, NRL operates as the Navy's full-spectrum corporate laboratory, conducting a broadly based, multidisciplinary program of scientific research and advanced technological development directed toward maritime applications of new and improved materials, techniques, equipment, systems, and ocean, atmospheric, and space sciences and related technologies.

institute for nanoscience

world class facilities
&
a leader in nanoscience and technology

The U.S. Navy, known for its enormous aircraft carriers and nuclear submarines, now has the opportunity to exploit the world of the very small for its next generation of technology. Because it understands both nanoscience and the needs of the Navy, the Naval Research Laboratory is uniquely positioned to conduct innovative research to benefit our warfighters and our nation.

NRL opened the Institute for Nanoscience in 2003 to conduct multidisciplinary research at the intersections of the fields of materials, electronics, and biology in the nanometer size domain. The objective of the Institute's programs is to provide the Navy and the DoD with scientific leadership in this complex, emerging area and to identify opportunities for advances in future defense technology.

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CAPT Paul C. Stewart
Commanding Officer

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