NAVAL RESEARCH LABORATORY

SPECTRA

THE MAGAZINE OF THE NAVY'S CORPORATE LABORATORY

SPRING 2012

NRL OPENS THE LABORATORY FOR AUTONOMOUS SYSTEMS RESEARCH

NAVAL RESEARCH LABORATORY

THE LEADING EDGE

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The U.S. Naval Research Laboratory (NRL) celebrates the opening of the Laboratory for Autonomous Systems Research (LASR) in March 2012. This issue of SPECTRA recognizes this event by focusing several articles on NRL's autonomous systems research activities and contributions.

NRL's work in autonomous systems is not a new venture. Since 1923, NRL researchers have been on the cutting edge of autonomous systems research. With the opening of the LASR, NRL scientists and engineers will have access to specialized facilities that can support highly innovative, multidisciplinary research in autonomous systems.

NRL has long been known for its multidisciplinary research efforts. Building on that rich research legacy, the LASR will bring together scientists and engineers from varying disciplines to study and solve military requirements, using autonomous systems.

LASR is a one-of-a-kind facility providing facilities and environments that simulate littoral, desert, and tropical locations. There are also high bay spaces that can be configured to support the components of research prototype systems. Armed with these facilities, NRL researchers will be equipped to lead the way in identifying and solving future technology problems for current and future warfighters.

We hope you enjoy this issue of SPECTRA and share it with others. To request additional copies or more information, please email spectra@nrl.navy.mil.

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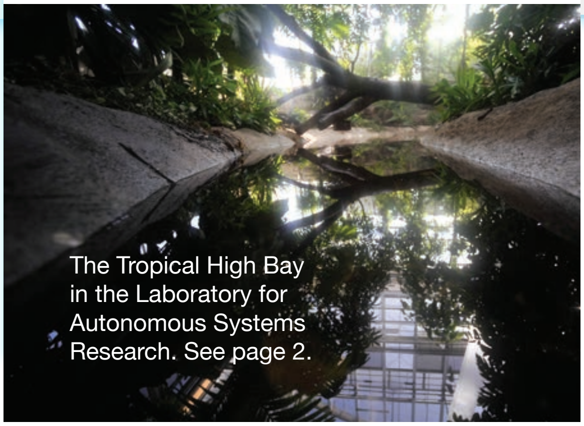

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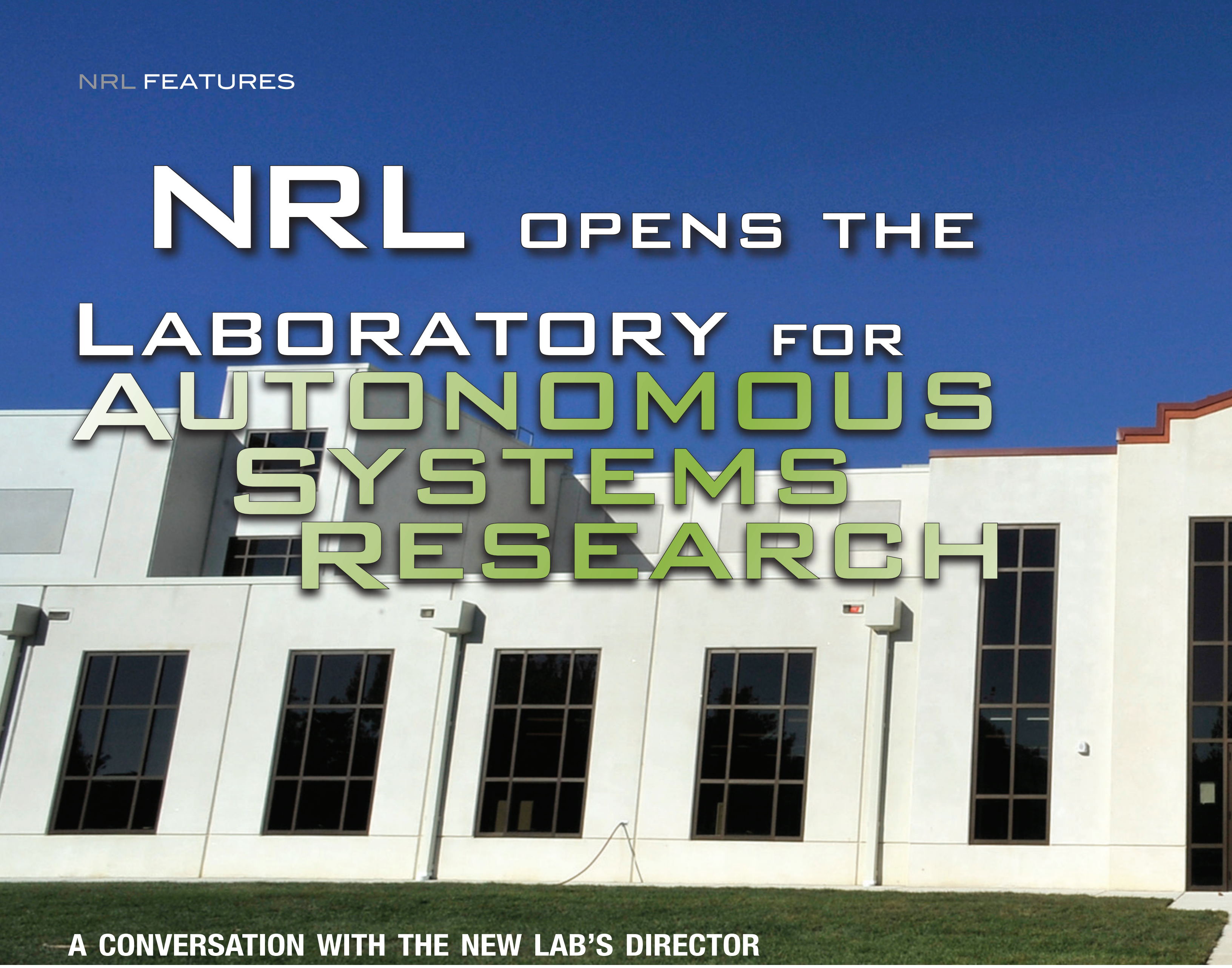


NRL opens the Laboratory for Autonomous Systems Research

A CONVERSATION WITH THE NEW LAB'S DIRECTOR

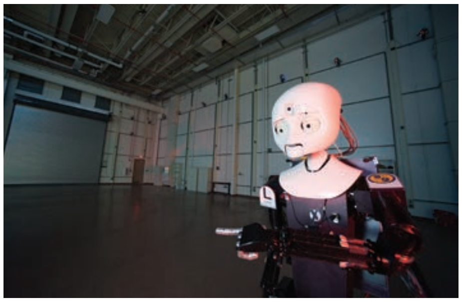
THE NAVAL RESEARCH LABORATORY in Washington, D.C., opened the Laboratory for Autonomous Systems Research (LASR) this year. This new laboratory will become a nerve center for autonomy research for the Navy and Marine Corps. The one-of-a-kind laboratory provides specialized facilities to support highly innovative research in intelligent autonomy, sensor systems, power and energy systems, human–system interaction, networking and communications, and platforms. The LASR capitalizes on the broad multidisciplinary character of NRL, bringing together scientists and engineers from diverse backgrounds to tackle common challenges in autonomy research at the intersection of their respective fields. The objective of the LASR is to enable continued Navy and Department of Defense scientific leadership in autonomy and to identify opportunities for advances in future defense technology.

SpectrA spoke with Alan Schultz, director of the new LASR, to learn about the facilities in the lab and the kind of research to be conducted there.

Tell us about the capabilities of LASR.

The new facility has a number of high bay environments and laboratories with many unique features to support research in autonomous systems.

The ***Prototyping High Bay*** is 150 ft by 75 ft by 30 ft high. This space can be used for small autonomous air vehicles, autonomous ground vehicles, and of course the people who will interact with them. The most unique feature of this space is a motion capture system, which allows us to track up to 50 objects and gather high-accuracy ground truth data of all positions of these tracked objects at 120 Hz. Our tracking system currently has the largest capture volume in existence. In addition, we have high-speed cameras on motorized pan/tilt heads that can be automatically cued by the motion capture system, enabling us to record video of specific targets. We have an audio system that allows us to inject directional sound into the environment; we can inject, for example, the sound of troops marching from the southeast to the northwest, or environmental background noises. We can flood a 40 ft by 40 ft area to a 4-inch depth, so we can simulate a shallow body of water, or allow sensors from an air vehicle to see specular reflections. Lighting is adjustable, and nighttime conditions can be simulated. Four labs overlook the high bay and can be used for testing human interaction with remote systems, and as control rooms.



Littoral High Bay

The ***Tropical High Bay*** is a 60 ft by 40 ft greenhouse that contains a re-creation of a southeast Asian rain forest, with temperatures that average 80 degrees and 80 percent humidity year round. Rain events of up to 6 inches per hour can be generated, allowing us to test autonomous systems, sensors, and communications in these harsh environments.

The ***Littoral High Bay*** features a 45 ft by 25 ft by 5.5 ft deep pool. This pool has a 16-channel wave generator, allowing us to create directional waves. In addition, the far side of the pool contains a structure allowing us to put a slope on that end of the pool. We have materials such as sand, dirt, and gravel that can then be put into the pool, allowing us to create surf-like conditions. The wave generator and slope mechanism can be removed with our overhead crane for those who need a constant depth and the full length of the pool. The Littoral High Bay will also have a variety of sediment tanks for testing sensors and energy-harvesting devices.

The ***Desert High Bay*** contains a 40 ft by 14 ft area of sand 2 feet deep, and contains 18-foot-high rock walls that allow testing of robots and sensors in a desert-like environment. We can introduce blowing sand, and can control the lighting in that environment.

Desert High Bay

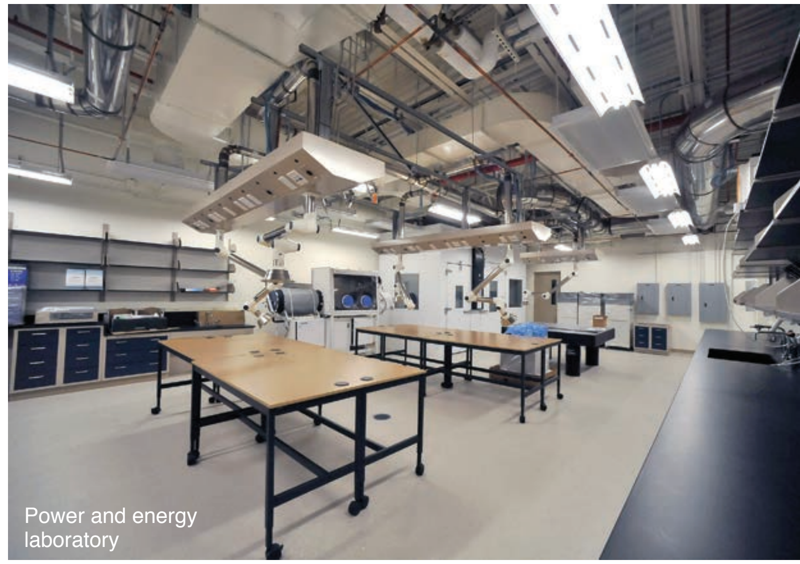
We have specialized laboratories for human–systems interaction, sensors, and power and energy. The four human–systems interaction labs overlook the Prototyping High Bay and can be used, as described earlier, as control rooms for human-subject experiments, or for development of autonomy software. These labs contain eye trackers (useful for studying how people work with advanced interfaces for autonomous systems) and multi-user/multi-touch displays. The sensor lab contains environmental chambers (including a smaller chamber where temperature, humidity, and barometric pressure can be controlled and a large walk-in chamber with control of temperature and humidity), an anechoic chamber, and an aerosol test facility.

Who will work in LASR?

LASR is an NRL-wide resource. NRL researchers who have relevant projects can register to use the facility using our online registration process that will be available soon. In that process, the principal investigator will describe the work to be done and which of our labs and environments they intend to use. The lab director and facility manager will then determine appropriateness of the project and whether space is available. Priority will be for multidisciplinary research in autonomous systems. Once the project is approved, researchers may then create experimental setups in our scheduling system and reserve time for specific experiments.

Will LASR be opened to outside researchers or is it only for NRL scientists and engineers?

While the facility was created to support NRL research, outside collaborators on funded projects will be able to work with NRL scientists on collaborative projects in the facility. The facility is not generally available for rent.



Power and energy laboratory

Tropical High Bay

What types of research will be conducted in LASR?

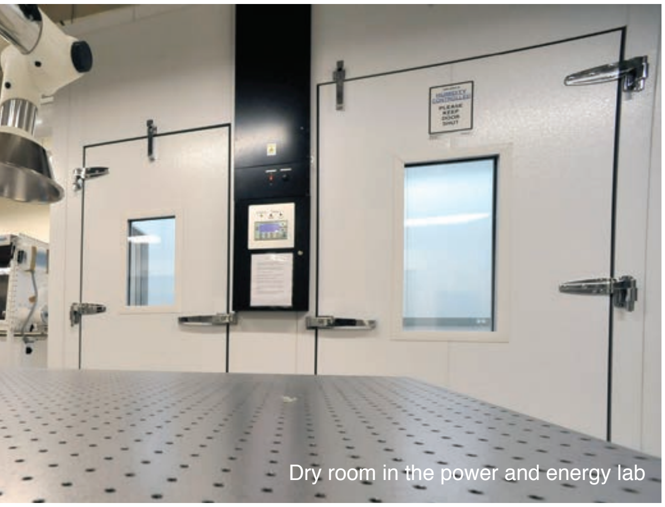
LASR will support a broad range of research related to autonomous systems, from basic to applied, and for integration across different disciplines. For example, while we do expect to have a lot of research involving autonomous vehicles, autonomy goes beyond vehicle platforms to autonomous systems for self-configuring and self-healing networks, autonomous sensor networks, and software to aid the warfighter in decision making. The lab will support research in power and energy systems and sensors that are used as payloads and that are part of the autonomous systems.

To show the breadth of the science, a few of the research projects that are already slated to start work in the building include Damage Control Technologies for the 21st Century, which is working on advanced shipboard firefighting technology, including autonomous firefighting robots, and the Large-Displacement UUV, where research is being performed on sensors, power and energy, and on the technology for testing and evaluating autonomous control algorithms.

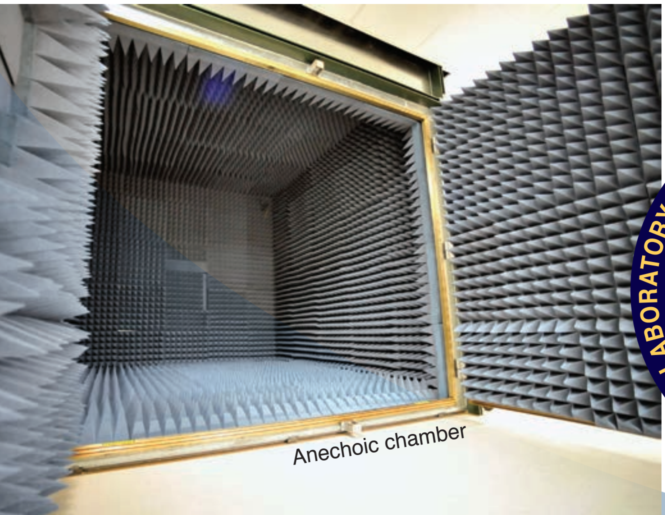
How are NRL researchers uniquely positioned to take full advantage of a laboratory like LASR?

NRL is uniquely positioned because of the breadth and depth of our science, and because we have the underlying science needed for all aspects of autonomous systems. As I went around to NRL's various divisions to brief our scientists about the new facility, I realized that virtually all of our research divisions have a role, whether it's biomolecular researchers developing CBRNE sensors, material scientists developing novel ways to embed antennas or electronics into vehicle structures, or psychologists studying how our warfighters will work with these systems. The potential for cross-disciplinary work is huge, and I am already seeing folks working together to solve the bigger problems in autonomous systems that cannot be solved when these groups work in isolation.

Walk-in environmental chamber



Dry room in the power and energy lab



Anechoic chamber

What do you see being accomplished using LASR that is not currently being accomplished in NRL's individual research divisions?

While many of our divisions already work together in interesting ways to solve these bigger problems, LASR will allow us to do larger scale integration of the science and to test out our ideas before we go to the field. Our facility gives us a cost-saving method for testing out concepts and ideas before we go to the expense of field trials. In essence, it bridges the gap between laboratory work and field experiments.

Alan C. Schultz is Director of NRL's Navy Center for Applied Research in Artificial Intelligence, in addition to being selected as the first Director of NRL's new Laboratory for Autonomous Systems Research. He has 26 years of experience and over 100 publications in autonomous systems, robotics, human–robot interaction, and machine learning, and is responsible for establishing and running the robotics laboratory at NRL. Mr. Schultz was selected to teach at the first IEEE Robotics and Automation Society Summer School on Human–Robot Interaction, has been editor of several collections in multirobot systems, and has chaired many conferences and workshops in robotics and human–robot interaction. He has been principal investigator on numerous ONR, DARPA, NASA, and DOE grants. Mr. Schultz received his M.S. in computer science from George Mason University in 1988. He is the recipient of 20 Navy Special Achievement awards for significant contributions, and the Alan Berman Research Publication Award. His research is in the areas of human–robot interaction, autonomous systems, and adaptive systems.

LABORATORY FOR AUTONOMOUS SYSTEMS RESEARCH • WASHINGTON, D.C. •

Darrell King is the Facilities Manager for the newly opened Laboratory for Autonomous Systems Research. He started work in the position in September 2010 soon after construction for the Laboratory got underway. King provides complete facility and equipment support for the LASR, with responsibility for day-to-day operations.

King's daily responsibilities range from training new users of the Lab, to maintaining the greenhouse and plants, to providing technical expertise on the LASR equipment and facilities.

Prior to this position, King was the Facilities Manager at NRL's Institute for Nanoscience from 2001 to 2010. From 1985 to 2001, he worked with Dr. Gary Prinz in the Materials Science and Technology Division as a technician involved with the thin film growth of magnetic materials. From 1975 to 1985, he worked in the Electronics Science and Technology Division as a technician involved in bulk and single crystal growth of semiconductor materials and post-growth processing.

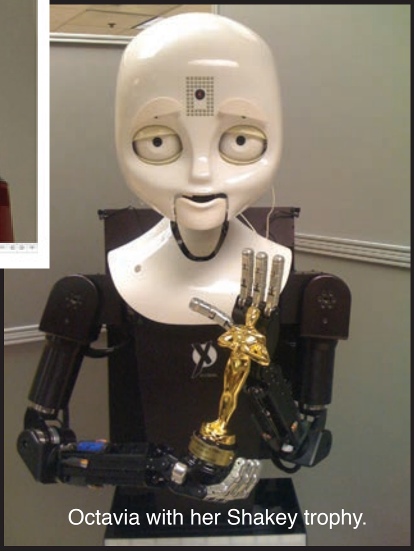
NRL AI Videos Win Awards

Naval Research Laboratory scientists won the "Best Educational Video" award at the Association for the Advancement of Artificial Intelligence's (AAAI) annual conference in San Francisco in August 2011.

Their award-winning video, "Robotic Secrets Revealed, Episode 002," demonstrates research on robot perception (including object recognition and multimodal person identification) and embodied cognition (including theory of mind, or the ability to reason about what others believe). The NRL team used a highly entertaining vignette that included two people interacting with two robots. The video can be seen at http://www.nrl.navy.mil/aic/iss/aas/CognitiveRobotsVideos.php.

The team that created the video works in NRL's Navy Center for Applied Research in Artificial Intelligence. Team members include Dr. Laura Hiatt, Dr. Anthony Harrison, Dr. Ed Lawson, Dr. Eric Martinson, and Dr. Greg Trafton. This is the second time NRL researchers have been recognized with a video award at the AAAI conference. In 2009, their video "Robotic Secrets Revealed, Episode 001" won the prize for "Most Informative Video."

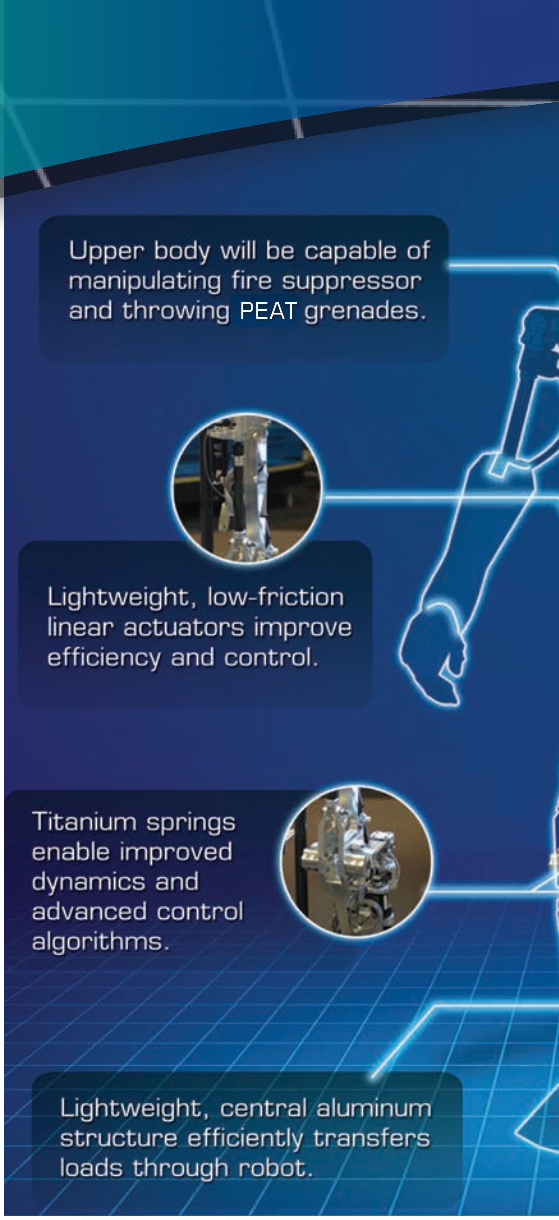
Octavia and George star in "Robotic Secrets Revealed, Episode 002."



Octavia with her Shakey trophy.

The goal of the AAAI video competition is to show the world how much fun artificial intelligence is by documenting exciting artificial intelligence advances in research, education, and application. The rules are simple: Compose a short video about an exciting artificial intelligence project, and narrate it so that it is accessible to a broad online audience. The developers of award-winning videos receive Oscar-like trophies, called "Shakeys" in honor of SRI International's Shakey robot and its pioneering video.

NRL Designs Robot for Shipboard Firefighting

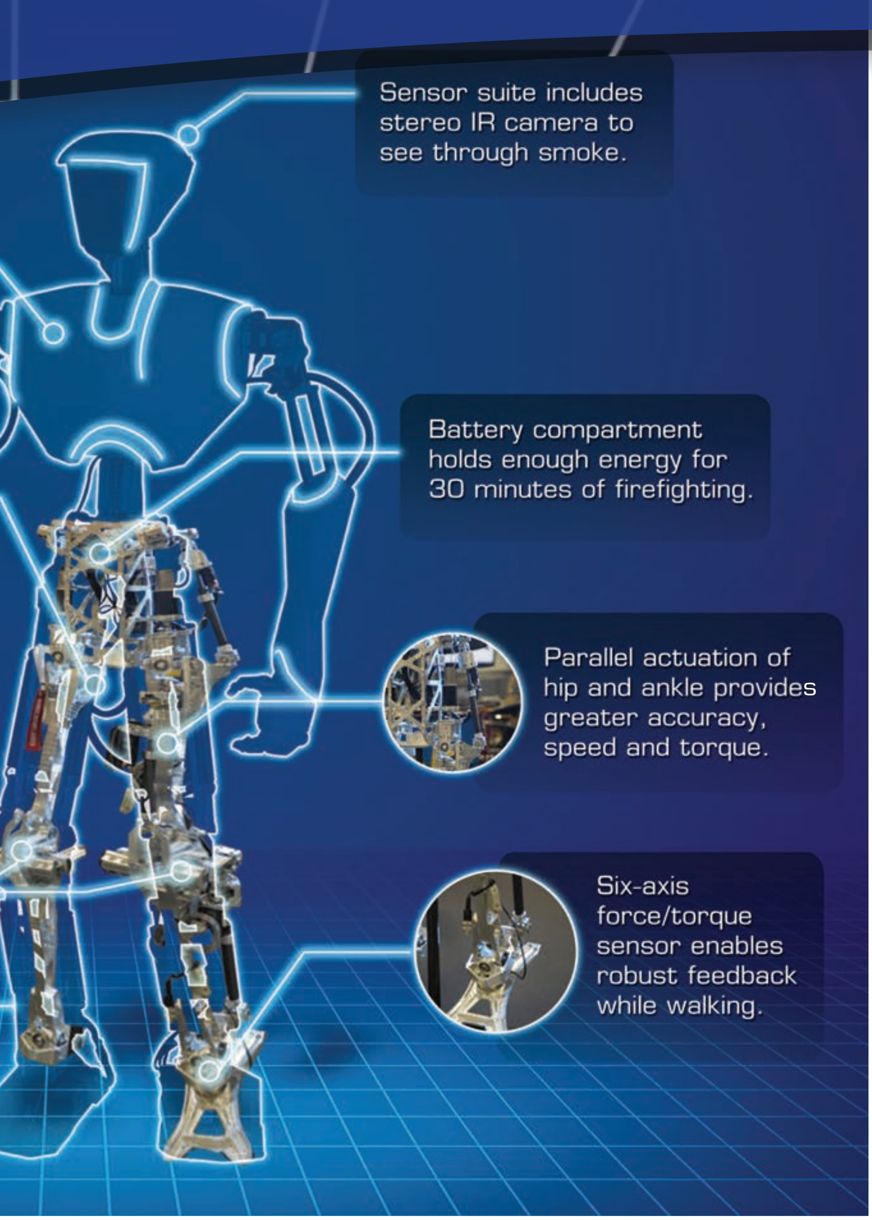


To advance future shipboard firefighting capabilities, scientists at the Naval Research Laboratory have formed an interdisciplinary team to develop a humanoid robot that could fight fires on the next generation of combatants. A humanoid-type robot was chosen because it was deemed best suited to operate within the confines of an environment that was designed for human mobility and offered opportunity for other potential warfighting applications within the Navy and Marine Corps.

The firefighting robot, called the Shipboard Autonomous Firefighting Robot (SAFFiR), is being designed to move autonomously throughout the ship, interact with people, and fight fires, handling many of the dangerous firefighting tasks that are normally performed by humans. The humanoid robot should be able to maneuver well in the narrow passages and ladderways that are unique to a ship and challenging for most older, simpler robots to navigate.

The robot is designed with enhanced multimodal sensor technology for advanced navigation and a sensor suite that includes a camera, gas sensor, and stereo infrared camera to enable it to see through smoke. Its upper body will be capable of manipulating fire suppressors and throwing PEAT (propelled extinguishing agent technology) grenades. It will be battery powered, with enough energy for 30 minutes of firefighting. Like a sure-footed sailor, the robot will also be capable of walking in all directions, balancing in sea conditions, and traversing obstacles.

Another key element of the SAFFiR development is to allow damage control personnel and the robot to work cohesively as a team. Algorithms are being developed to allow autonomous mobility and decision making by the robot as a team member. To enable natural interaction with a human team leader, the robot will have multimodal interfaces that will enable the robot to track the focus of attention of the human team leader, as well as to allow the robot to understand and respond to gestures, such as pointing and hand signals. Where appropriate, natural language may also be incorporated, as well as other modes of communication and supervision.



The Virginia Tech CHARLI-L1 robot. NRL's firefighting robot will be a follow-on version to this one.

Researchers from Virginia Tech and the University of Pennsylvania are working with NRL on the project. They plan to test the firefighting robot in a realistic firefighting environment aboard the ex-USS *Shadwell*, NRL's fire research ship, in late September 2013.

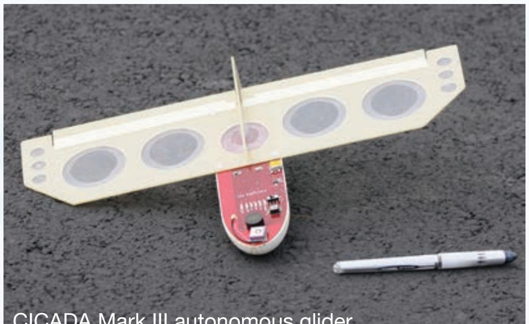
The Navy Technology Center for Safety and Survivability, located at NRL in Washington, D.C., carries out research aimed to solve current and future Navy problems regarding combustion, fire extinguishment, fire modeling and scaling, damage control, and atmosphere hazards. The Center has unique fire research facilities that include pressurable chambers up to a 10,000 cubic foot capacity at the Center's test site at NRL's Chesapeake Bay Detachment in Calvert County, Maryland. The Center also has custody of the fire test ship ex-USS Shadwell (LSD 15) located in Mobile, Alabama, where full-scale fire and damage control tests are conducted using the reality conformations of active duty sailors. Using the ex-USS Shadwell, NRL scientists are able to enhance their technology base for introducing advanced damage control concepts to the Fleet. The ship provides a unique opportunity to realistically experience a true damage control environment, to create a partnership between the technical and Fleet communities, and to take advantage of new insights gleaned during full-scale experimentation.

The Navy Center for Applied Research in Artificial Intelligence (NCARAI) has been involved in both basic and applied research in artificial intelligence, human factors, and human-centered computing since its inception in 1981. NCARAI, part of the Information Technology Division within NRL, is engaged in research and development efforts designed to address the application of artificial intelligence technology and techniques to critical Navy and national problems. The NCARAI is developing the algorithms that allow the firefighting robot to work naturally with human firefighters, as well as high-level reasoning capabilities.

The Laboratory for Autonomous Systems Research provides specialized facilities to support highly innovative, multidisciplinary research in autonomous systems, including intelligent autonomy, sensor systems, power and energy systems, human–systems interaction, networking and communications, and platforms (see p. 2).

Autonomous Deployment Demonstration Program Completes Flight Testing

The Naval Research Laboratory Vehicle Research Section has successfully completed flight tests for the Autonomous Deployment Demonstration (ADD) program. The final demonstration took place September 1, 2011, at the Yuma Proving Ground (YPG), Arizona, and consisted of a series of eight balloon-drops at altitudes of up to 57,000 feet, delivering sensor-emplacement Close-In Covert Autonomous Disposable Aircraft (CICADA) vehicles within 15 feet of their intended landing locations.


CICADA Mark III autonomous glider

The ADD concept is to enable small unmanned air vehicles (UAVs) equipped with sensor payloads to be launched from aircraft (manned or unmanned), balloons, or precision guided munitions, and dispersed in selectable patterns around designated areas.

"The mission profile is straightforward," says Chris Bovais, an aeronautical engineer and flight test coordinator in the NRL Vehicle Research Section. "The CICADA is dropped from another airborne platform, flies to a single waypoint, and then enters an orbit. It descends in that orbit until it reaches the ground."


The Tempest UAV with two wing-mounted CICADA vehicles.

The ADD test crew prepares to launch a weather balloon to carry the Tempest UAV and CICADA gliders to an altitude nearly 60,000 feet above the desert floor.

The NRL-developed CICADA Mark III UAV is a glider; it has no onboard propulsion source. Therefore, it requires another airborne platform to get it to an altitude such that it can glide to its destination. Its lack of a motor and small size make it nearly undetectable in flight.

The ADD field trials successfully demonstrate that the CICADA can perform a precision delivery of a notional payload after being dropped from a "mother ship" or being carried aloft by a balloon. Standoff distances of 30 nautical miles and altitudes up to 57,000 feet were demonstrated, with an average landing error of 15 feet from the commanded location.

CICADA MK III

A CICADA Mark III is carried beneath the left wing of the Tempest UAV at 53,000 feet, after release from the balloon and before releasing the CICADA.

During the demonstration, the UAV ensemble was lifted to altitude using balloons operated by Aerostar International. A Tempest UAV, built by UASUSA (Boulder, Colorado), with two CICADA vehicles attached on wing-mounted pylons, was carried aloft to altitudes approaching 60,000 feet. The Tempest was released from the balloon, autonomously executed a pull-up maneuver, and then carried the two CICADAs to a drop location. Each CICADA vehicle was then released from the Tempest and autonomously flew to the preprogrammed target waypoint.

"Many remote sensors are currently hand emplaced," said Bovais. "The CICADA allows for the low-cost delivery of multiple precision-located sensors without placing the warfighter in harm's way."

The CICADA Mark III is a unique vehicle. The airframe is simply a printed circuit board also serving as the autopilot, the first known multipurpose airframe/avionics implementation of its kind. This novel construction method significantly reduces assembly time, minimizes wiring requirements, and enables the manufacture of low-cost and rugged micro air vehicles. The airframe shape is easily scaled to accommodate various payload sizes and potential acoustic, magnetic, chemical/biological, and SIGINT sensors. Unique to this construction technique, additional electronic payloads can be inserted into the system by updating the printed circuit board artwork and "re-winging" the aircraft.

A custom autopilot for the CICADA, both hardware and software, was developed by the Vehicle Research Section to be both inexpensive and robust. The only flight sensors are a 5 Hz GPS receiver and a two-axis gyroscope. Although having minimal sensors, the navigation solution and the flight controller proved to be quite robust during in-flight testing, routinely recovering from tumbling launches. The flight controller also included a custom NRL algorithm that accurately estimated wind speed and magnitude, despite having no air data sensors on board.

"The CICADA allows for the low-cost delivery of multiple precision-located sensors without placing the warfighter in harm's way."

AUTONOMOUS SYSTEMS AT NRL

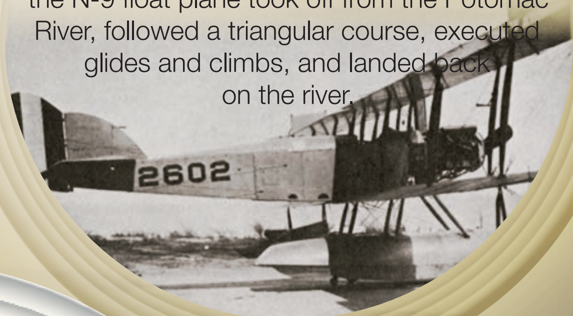
The First 25 years

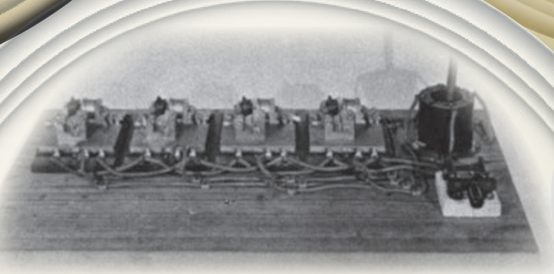
1923 Electric Dog

Working toward the development of pilotless aircraft and "flying bombs" for the Navy, NRL devised a radio remote-control system that allowed several operations to be controlled at once, as required in piloting an aircraft. A control switch with a vertical handle, similar to the joystick on an aircraft, could operate selective relays simultaneously to control the many necessary functions. This system was first applied to a three-wheel cart, christened the Electric Dog, which could be seen wandering about on NRL's driveways.

1924 Remote-Controlled Pontoon Plane

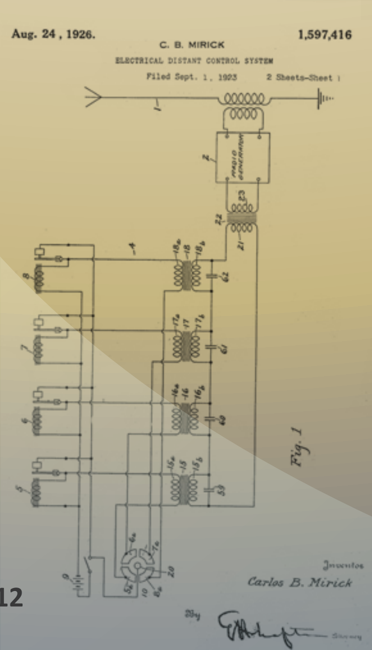
NRL developed the control system for the first U.S. flight of a radio-controlled pilotless aircraft. Remotely controlled from the ground, the N-9 float plane took off from the Potomac River, followed a triangular course, executed glides and climbs, and landed back on the river.





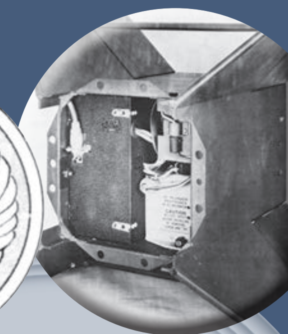
1926 Joystick Remote Control Circuit Patent

NRL engineer C.B. Mirick patented his system for remote radio control of pilotless aircraft and of "any circuits or objects which are to be controlled at a distance." U.S. Patent no. 1,597,416, "Electrical Distant-Control System," Aug. 24, 1926. "My invention relates broadly to distant control systems, and more particularly to a control circuit for a radio transmitter, and a selectively responsive circuit for a radio apparatus whereby particular controls may be caused to function individually or simultaneously... My control system is particularly applicable in maneuvering aircraft without a pilot."



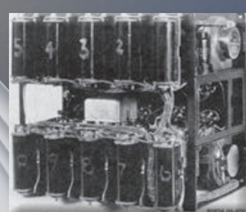
1930s
Remote-Controlled Decoy Battleships

For exercises to test the vulnerability of ships to air bombing, NRL devised a radio remote-control system to maneuver the warships USS *Stoddert* and USS *Utah*, which had been converted to target ships. The steering and throttle controls were operated through selector switches based on the teletype mechanism using the Baudot code.



1943
Radio-Guided Bombs

NRL was responsible for development of the radio remote-control units for the Azon ("azimuth only"), Razon ("range and azimuth"), Gorgon, and Gargoyle guided bombs. The Azon, sometimes called an early "smart bomb," was put into service in 1944 to bomb enemy bridges, railroads, and other targets.

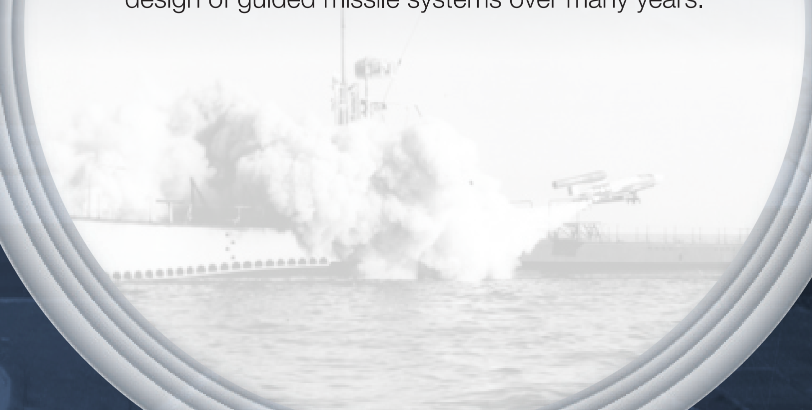


1936 – WWII
Anti-Aircraft Target Drones

The Navy needed more realistic anti-aircraft practice targets than target sleeves towed by piloted aircraft, so NRL developed the radio-control system for an unmanned aircraft that could be controlled by a "mother plane" up to 25 miles away. Target "drones" became widely used and led to rapid improvement in fire control systems. Hundreds of F6F and other type aircraft were converted to drones for gunnery training, evaluation of defense procedures, and to carry out simulated "Japanese suicide" attacks. After the war, radio-guided drones collected data on nuclear explosions during the Bikini Atoll tests, telemetering the data to safe observation points aboard ship.

1947
Loon Guided Missile System

The Navy initiated a number of missile programs toward the end of WWII, and NRL developed the guidance systems for several of them. Loon, one of the earliest, was the first guided missile to be launched from a submarine, USS *Cusk*. NRL research in kinematics, dynamic stability, noise dispersion, flame plasmas, and other fields contributed to the design of guided missile systems over many years.



AUTONOMOUS SYSTEMS AT NRL

The Most RECENT years

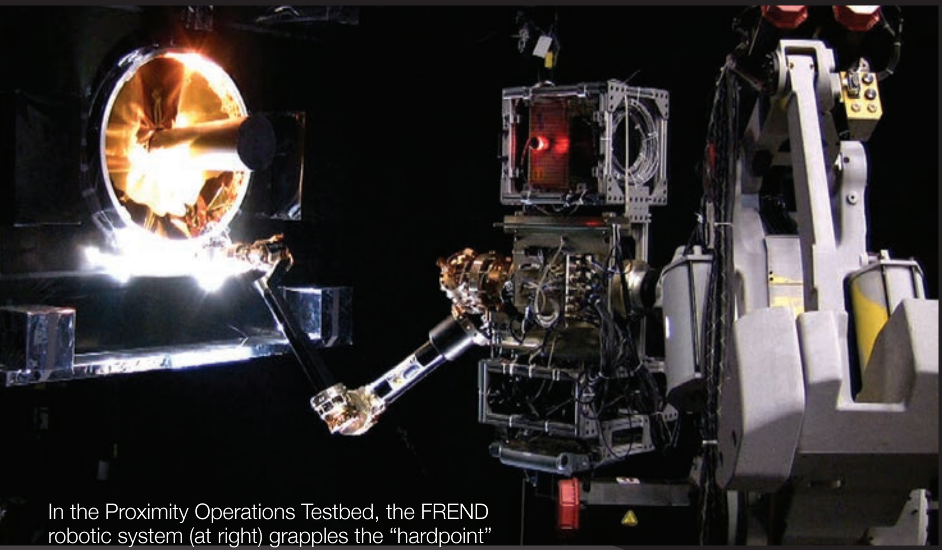
2008 Autonomous Soaring

The ALOFT unmanned and unpowered sailplane, with a nominal endurance of 3 minutes, was able to fly for 5.3 hours and 70.5 miles by exploiting naturally occurring air currents, similar to a soaring bird. Custom software algorithms detected the presence of rising air using onboard sensors, estimated the center of any nearby thermals, and redirected the autopilot to orbit in a more advantageous location. This technology can be implemented on existing UAVs with a software upgrade and thereby extend the vehicle's endurance and range without the need for additional fuel or hardware.

The Autonomous Locator of Updrafts (ALOFT) sailplane.

2008 Embodied Cognition

NRL developed the first cognitively plausible robot architecture, ACT-R/E. Based on what is known about human reasoning and memory (from both psychological studies and fMRI data), ACT-R/E, using the robot's perceptual inputs, performs reasoning and decision making in a way that is similar to how people reason, and allows the robot to interact naturally with people.



In the Proximity Operations Testbed, the FREND robotic system (at right) grapples the "hardpoint" interface of a satellite (left).

2008 FREND

Autonomous Rendezvous and Docking

In the Front-end Robotics Enabling Near-term Demonstration project, NRL developed and ground-demonstrated guidance and control algorithms to allow a robotic servicing vehicle to autonomously rendezvous and dock with a satellite not predesigned for docking. The demonstration was completed in a realistic spaceflight environment under full autonomy with no human-in-the-loop assistance.

2009 Ion Tiger

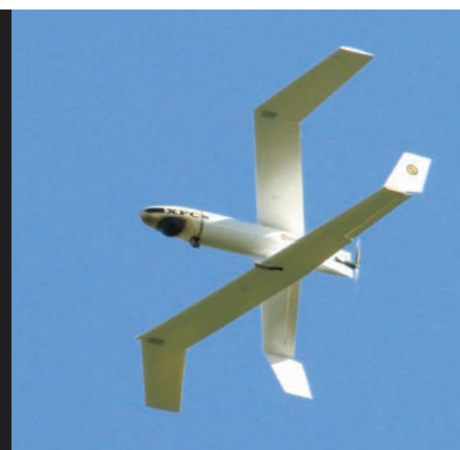
This fuel-cell-powered UAV flew for 26+ hours with a 5-lb payload by using a high-energy hydrogen fuel cell system for electric propulsion, exceeding by 6× the endurance provided by batteries. With this demonstration, NRL created a new class of stealthy, small unmanned air vehicles capable of "big vehicle missions." A new liquid hydrogen fuel tank may extend the UAV's endurance to 72 hours.

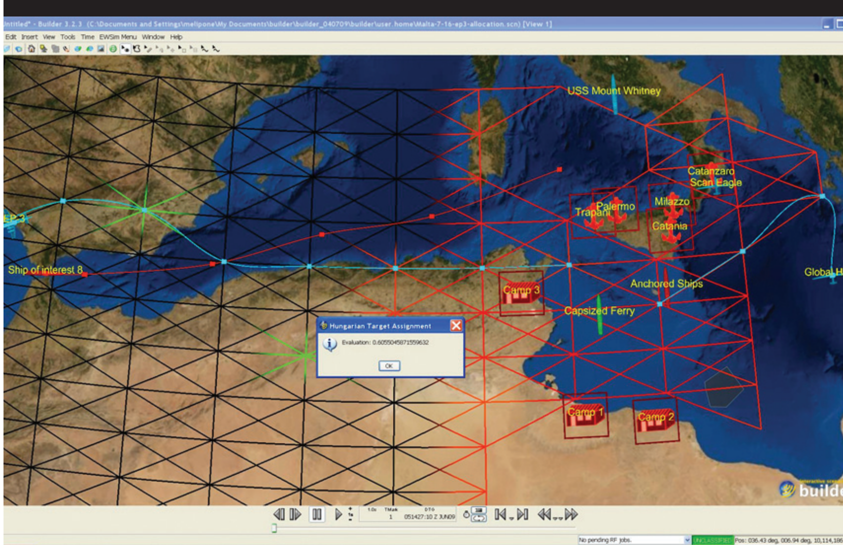
2009 Predicting and Preventing Procedural Errors

Using a combination of a theory of human memory (Memory for Goals) and an eyetracker, NRL created a system that can predict when an operator is about to make a procedural error before the error actually occurs, and give a just-in-time cue to prevent the error from being made.

2009 XFC

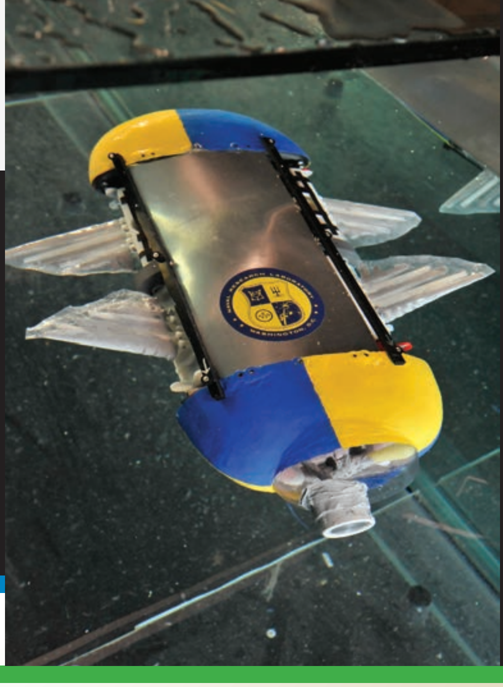
The eXperimental Fuel Cell unmanned aerial system is a fully autonomous, affordably expendable surveillance platform. The folding-wing UAV ejects from a transport tube, unfolds to its X-shaped configuration, and can fly for 6 hours powered by a hydrogen fuel cell. XFC is being modified for launch from a submarine.





2009 Optimization of ISR Platforms to Improve Signal Collection in Maritime Environments

NRL developed intelligence, surveillance, and reconnaissance (ISR) optimization algorithms for tracking targets of interest in the maritime domain. The algorithms simultaneously optimize over several measures of interest (e.g., suspicious vessel movements, cargo, ports, piracy areas), "difficulty" measures (e.g., meteorological conditions), and ISR performance characteristics to improve signal collection for maritime domain awareness.



2010 Bio-Inspired Deformable Fin UUV

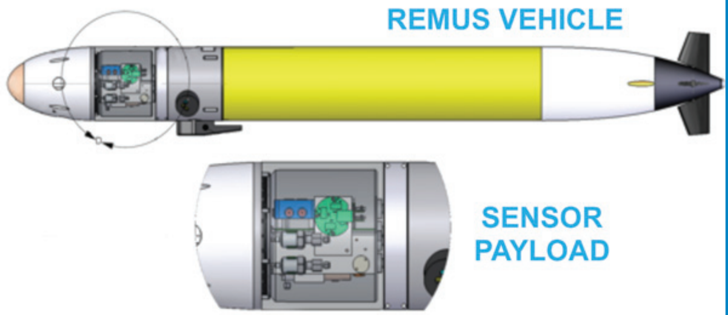
This unmanned undersea vehicle is propelled and controlled using fish-like, bio-robotic fins inspired by the bird wrasse, a coral reef fish. Actuation of individual ribs within each fin creates the curvatures necessary to generate the high-magnitude, variable-direction forces that enable precise, low-speed maneuvering in highly dynamic environments such as nearshore areas with currents and waves.

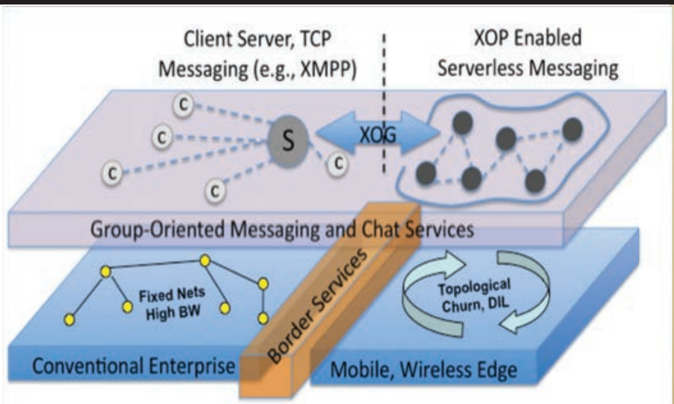
2010 Dynamic Goal Management

Goal-driven autonomy permits agents to automatically self-select their goals. This is particularly valuable for unmanned systems on long-duration deployments in complex environments.

2010 Flow Immunosensor Payload

NRL demonstrated its flow immunosensor payload on a Hydroid REMUS100 AUV. Low parts-per-billion levels of TNT were detected in a simulated plume while underway, and data acquisition was observed remotely in real time over a Web-based interface.



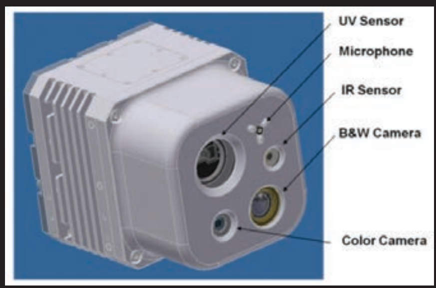


2010 Serverless Messaging Systems

NRL designed and developed serverless messaging systems that effectively operate in highly distributed and disruptive network environments. This system also supports proxy interfaces to standards-based clients and servers that cannot normally operate without server centralization. A serverless messaging system extension allows more autonomous operations by combining effective group discovery and collaboration among multiple communication nodes.

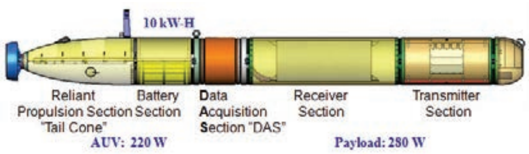
2010 Volume Sensor

This multisensor shipboard detection system provides early warning detection of flames, smoke, thermally hot objects, pipe rupture, and gas leaks through improved situational awareness. Based on data fusion, the system combines video image detection and machine vision software with spectral sensors and acoustic data inputs to correctly identify damage control events and discriminate against false positives.



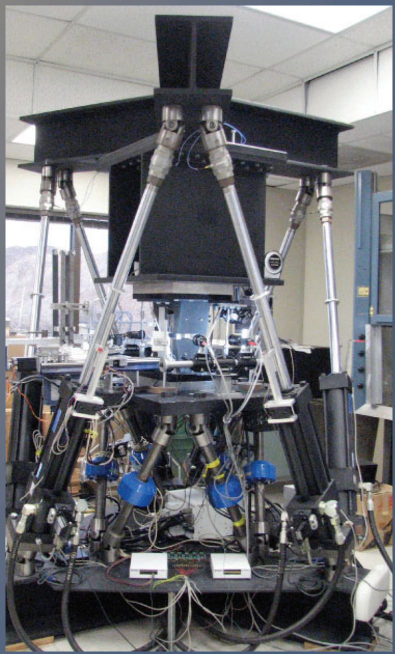
2010 Unmanned Semi-Submersible (USS)

NRL demonstrated this semi-submersible vehicle for shallow-water (2 to 200 m) bathymetry and sidescan surveying. It provides superior coverage rates (2× or greater) compared to unmanned surface vehicles and unmanned underwater vehicles, and is excellent for rapid response in hostile environments (combat, disasters).



2011 Low Frequency Broadband Sonar

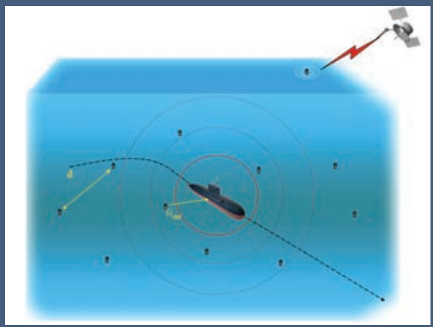
NRL's AUV-based broadband active sonar system for the high-performance detection and identification of underwater mines was transitioned to production. The "squint capable" synthetic aperture sonar measures scattering cross sections very precisely for identification based on structural acoustic features. The sonar is configured on a long-endurance, quiet AUV that navigates using a fusion of Doppler velocity measurement, fiber-optic gyroscope inertial navigation, and GPS. Deployment is anticipated on the Littoral Combat Ship and other platforms of opportunity.



2011 Robotic Materials Testing System

The NRL66.3 robotic system provides high-rate, fully automated testing to generate large quantities of response data for characterizing the behavior of complex materials. It features six-degree-of-freedom multiaxial loading, a wireless sensor network infrastructure, and a whole-field 3D optical method for measuring displacement and strain fields. Such a system is expected to influence the design, certification, and qualification methodologies used for sea and aerospace platforms built from high-performance composite and other anisotropic materials.

2011 Sea Nimbus



To improve detection of the very quietest underwater threats in shallow water environments, NRL created an autonomous distributed sensing and identification technology for short (<1 month) and long (2 to 10 months) duration monitoring over a wide area. This approach deploys large numbers of small, inexpensive, power-efficient/harvesting, and intercommunicating but otherwise unconnected underwater sensor nodes. Through their own cooperative decision making, they rise to the surface and RF-link contact information, and then re-submerge to continue monitoring.

2008 Gaze Following, Gesture Recognition, Conversation Tracking

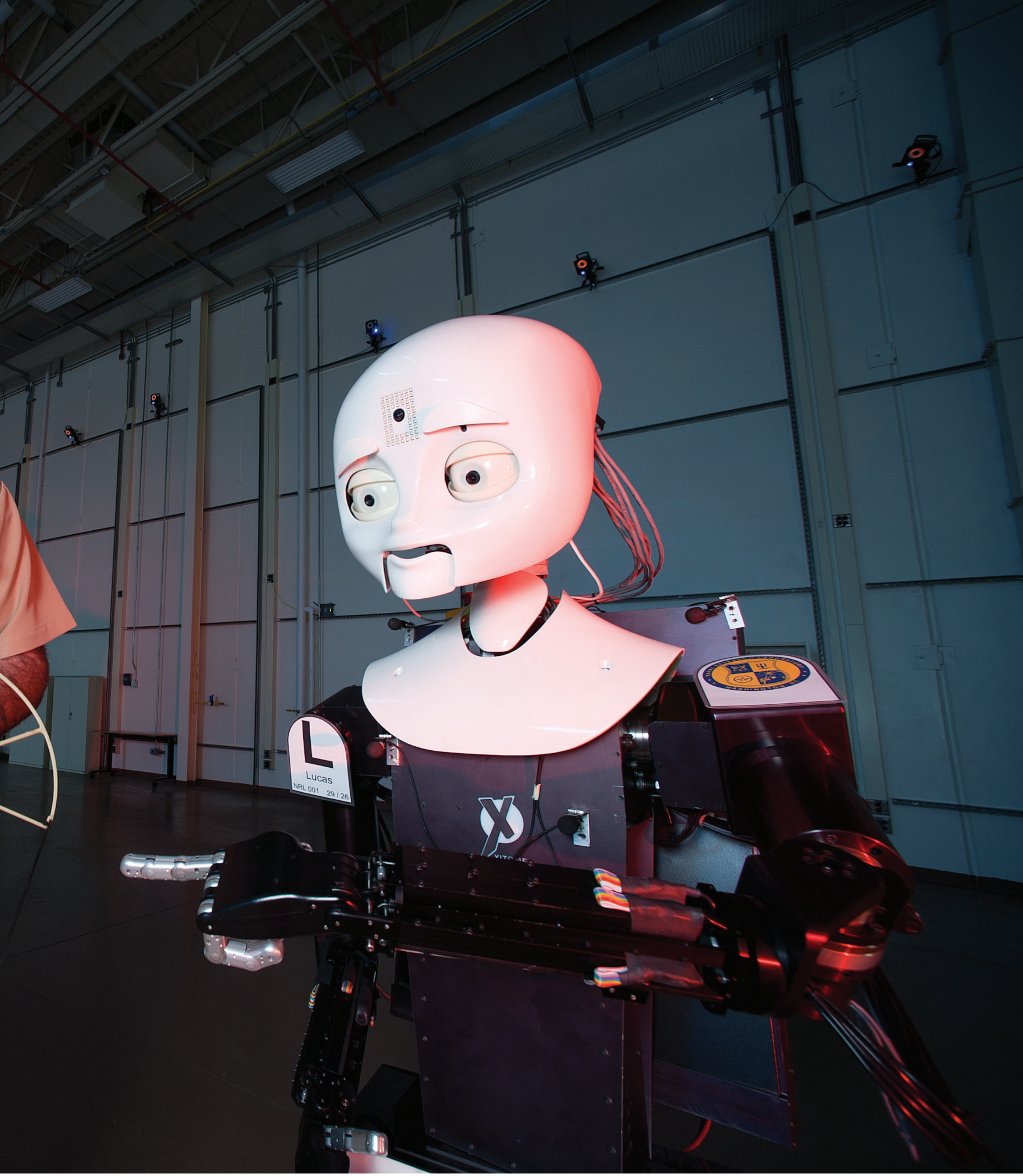
NRL has developed several systems for improving human–robot interaction in joint tasks. A system that uses a combination of visual perception algorithms and computational cognitive models allows a robot to track a person's head movements and understand that person's focus of attention. A system for learning and recognizing static and dynamic hand gestures (both one-handed and two-handed) allows autonomous systems to understand a person's communicative intent. A system that uses sound localization to guide a robot's vision system to find the speaker allows a robot to correctly track conversations.

2010 Theory of Mind

NRL developed a computational cognitive model of "Theory of Mind," which allows a robot to reason about what a person might believe. Using the model, the robot can detect when a person might not have a complete understanding of a situation, and offer more information.

Human-Robot Interaction

NRL Commanding Officer Capt. Paul C. Stewart gets guidance from Lucas, a Mobile, Dexterous, Social (MDS) robot, in the Prototyping High Bay in the Laboratory for Autonomous Systems Research. NRL scientists use Lucas and two other MDS robots, Octavia and Isaac, in human–robot interaction research and to develop cognitive robotic



systems. Areas of research include embodied cognition, voice and gesture recognition, and dynamic autonomy. Capt. Stewart holds an Ascending Technologies Pelican quadrotor mini air vehicle. NRL scientists use ten of these vehicles, each equipped with Vicon tracking markers, a GPS receiver, lidar, and cameras, to test new sensors and algorithms.

NAVY, Marine Corps tests AUTONOMOUS ZERØ-POWER Bathythermograph Sensors

The current device is composed of two chambers: the top, "dry" chamber containing the electronics, valves, solenoids, and timers; and the lower chamber, which contains the growth chamber (center tube) that becomes pressurized while bacteria are growing. The device is assembled on-site and has settings for duration between cycling (i.e., how often it comes to the surface, how long it should stay at the surface, and how long the valve is open to allow gas to fill the lower chamber). (Photo: *U.S. Navy Reserve/Tom Boyd*)

Developed by the Naval Research Laboratory Bioenergy and Biofabrication Section in the Chemistry Division and the Physical Acoustics Branch in the Acoustics Division, the Zero Power Ballast Control (ZPBC) is a technology that relies on microbial energy harvesting developments to enable unsupervised underwater sensing with subsequent surfacing and reporting capabilities.

With an ultimate goal of producing simple, small, power-efficient data harvesting nodes with variable buoyancy, the device will be able to monitor ocean temperatures with a stay time ranging from weeks to months and eventually years, providing a longer term than other mechanisms such as the Expendable Bathythermograph (XBT).

"Preliminary trials were successful in many ways," said Dr. Justin Biffinger. "The device surfaced and submerged periodically as designed via hydrogen gas produced from the microbial inoculum and growth medium, proving the device generated gas in sufficient quantity to produce buoyancy."

During testing of two ZPBC systems, the rise and fall of the devices were supported by onboard pressure and temperature sensor data and direct observation. The bacterial fuel source (inoculated gas production vessel) was then attached and the two ZPBC devices were deployed in situ off a military pier in Sattahip, Thailand, and held in place by mooring lines for seven days.

Using a low-power (1 to 10 milliwatt) timer, or only the rate of microbial gas generation that requires zero power input, the device can be alternatively configured to surface "on-demand." Sensors (e.g., acoustic, magnetic) attached to the ZPBC could be used to detect and classify, monitor the rise to the surface, report using RF or other communication, then re-submerge and continue monitoring operations.

In the future, the ZPBC will provide input for robust modeling of ocean temperatures and other parameters. The ZPBC could also be used to provide in-water optical data to enhance models for underwater visibilities, laser penetration depths, diver and target vulnerability assessments, electro-optical system performance predictions, and refining numerical models.

Military utility and scientific applications include use in Intelligence Surveillance and Reconnaissance (ISR), Anti-Submarine Warfare (ASW), Mine Warfare (MIW), Naval Special Warfare (NSW), and Meteorology and Oceanography (METOC). Continued prototyping could include georeferencing capabilities so that the device could be untethered in future tests.

The Office of Naval Research (ONR)/Naval Research Laboratory Reserve Program (Program 38) was tasked to conduct an experiment on ONR and NRL technologies which were incorporated into the U.S. Marine Corps Forces Pacific (MARFORPAC) Experimentation Center (MEC) Crimson Viper 2010 (CV10) Field Experiment.

Crimson Viper is a Thai-U.S. technology collaboration experimentation event jointly sponsored by the U.S. Pacific Command (USPACOM) and the Royal Thai Defense Science and Technology Department (DSTD). The MARFORPAC Experimentation Center, under the leadership of its Director, Mr. Shujie Chang, acts as the Thailand Science and Technology executive agent for USPACOM.

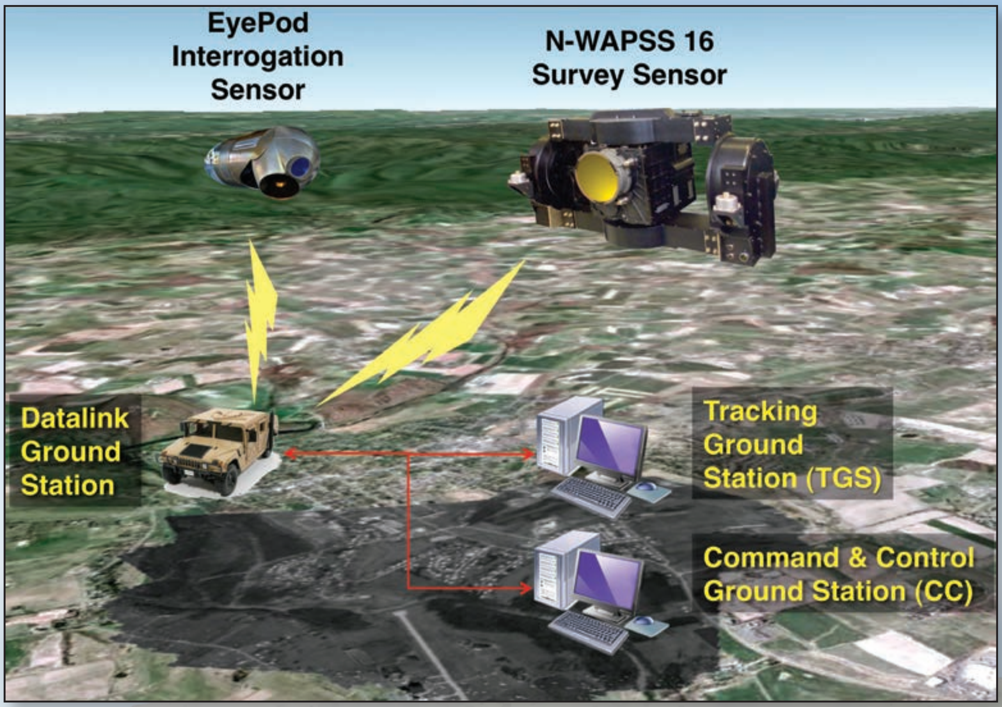
The bacterial fuel source (inoculated gas production vessel) was attached to the two ZPBC devices, which were then deployed in situ off a military pier in Sattahip, Thailand, and held in place by mooring lines for seven days. (Photo: *U.S. Navy Reserve/ Tom Boyd*)

The Bioenergy and Biofabrication Section has a wide range of biological expertise with a focus in energy and biofabrication applications. Bioenergy capabilities range from basic investigations into microbial metabolism and extracellular electron transfer mechanisms to more applied application of biological systems for energy production. Biofabrication efforts are focused on creating heterogeneous three-dimensional in vitro tissues via biological laser printing (BioLP) and the use of BioLP to isolate novel microorganisms from environmental samples.

The Physical Acoustics Branch conducts a research and technology program aimed at developing new opportunities for exploiting physical acoustic and structural acoustic related phenomena, processes, and technologies in areas and systems of importance to the Navy, the Department of Defense, and the Nation.

NRL *FLIGHT-TESTS* AUTONOMOUS Multi-Target, Multi-User TRACKING CAPABILITY

THE NAVAL RESEARCH LABORATORY AND THE SPACE DYNAMICS LABORATORY (SDL, NORTH LOGAN, UTAH), THROUGH THE SUPPORT OF THE OFFICE OF NAVAL RESEARCH (ONR), HAS SHOWN AN AUTONOMOUS MULTISENSOR MOTION-TRACKING AND INTERROGATION SYSTEM THAT REDUCES THE WORKLOAD FOR ANALYSTS BY AUTOMATICALLY FINDING MOVING OBJECTS, THEN PRESENTING HIGH-RESOLUTION IMAGES OF THOSE OBJECTS WITH NO HUMAN INPUT.



Intelligence, surveillance, and reconnaissance (ISR) assets in the field generate vast amounts of data that can overwhelm human operators and can severely limit the ability of an analyst to generate intelligence reports in operationally relevant timeframes. This multi-user tracking capability enables the system to manage collection of imagery without continuous monitoring by a ground or airborne operator, thus requiring fewer personnel and freeing up operational assets.

"These tests display how a single imaging sensor can be used to provide imagery of multiple tracked objects," said Dr. Brian Daniel, a research physicist in NRL's ISR Systems and Processing Section, "a job typically requiring multiple sensors."

During flight tests in March 2011, multiple real-time tracks generated by a wide-area persistent surveillance sensor (WAPSS) were autonomously cross-cued to a high-resolution narrow field-of-view (NFOV) interrogation sensor via an airborne network. Both sensors were networked by the high-speed Tactical Reachback Extended Communications (TREC) data link provided by the NRL Information Technology Division, Satellite and Wireless Technology Branch.

"The demonstration was a complete success," noted Dr. Michael Duncan, ONR program manager. "Not only did the network sensing demonstration achieve simultaneous real-time tracking, sensor cross cueing, and inspection of multiple vehicle-sized objects, but we also showed an ability to follow smaller human-sized objects under specialized conditions."

The network sensing demonstration utilized sensors built under other ONR-sponsored programs. The interrogation sensor was the precision, jitter-stabilized EyePod developed under the Fusion, Exploitation, Algorithm, and Targeting High-Altitude Reconnaissance (FEATHAR) program. EyePod is a dual-band visible/near-infrared and long-wave infrared sensor mounted inside a nine-inch gimbal pod assembly designed for small UAV platforms. The mid-wave infrared nighttime WAPSS (N-WAPSS) was chosen as the wide-area sensor, and has a 16 megapixel, large format camera that captures single frames at four hertz (cycles per second) and has a step-stare capability with a one hertz refresh rate.

Using precision geo-projection of the N-WAPSS imagery, all moving vehicle-size objects in the FOV were tracked in real time. The tracks were converted to geodetic coordinates and sent via an air-based network to a cue manager system. The cue manager autonomously tasked EyePod to interrogate all selected tracks for target classification and identification.

NAVY RESEARCHERS Investigate Small-Scale Autonomous Planetary Explorers

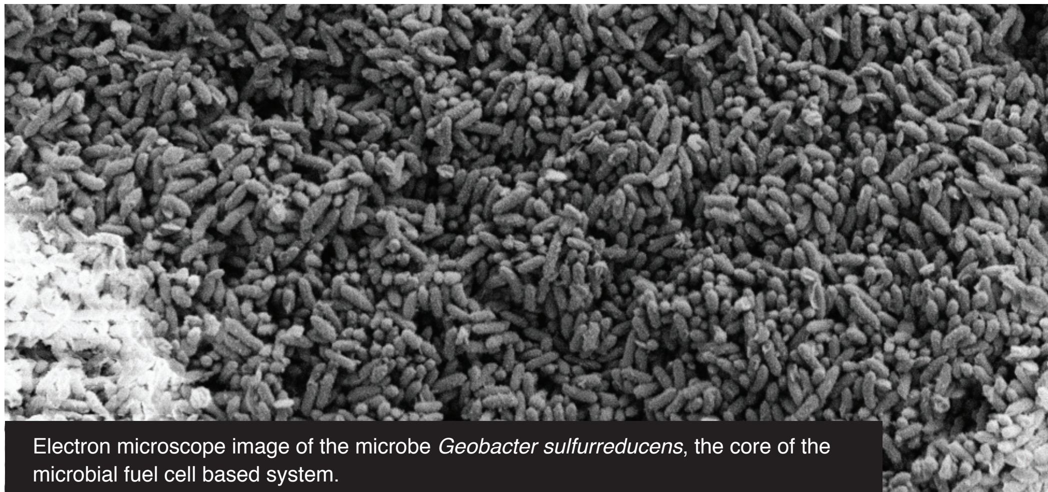
Robotic exploration to remote regions, to include distant planetary bodies, is often limited by energy requirements to perform, in repetition, even the simplest tasks. With this in mind, researchers at the Naval Research Laboratory are looking into a novel approach that could someday aid scientific space and planetary research without the need for power-intense options often used today.

Dr. Gregory P. Scott is pictured with laboratory prototype microbial fuel cells (MFCs) and the electronic power distribution hardware that will provide power to a prototype microrobotic system. These MFCs are under development by co-investigator Dr. Leonard Tender to provide a steady stream of power to the system. Low-power onboard electronics are being developed by co-investigator Dr. Stephen Arnold to collect and distribute power to the locomotion system and other onboard sensors.

Integrating the NRL-developed technologies in microrobotics, microbial fuel cells, and low-power electronics, space robotics scientist Dr. Gregory P. Scott at NRL's Spacecraft Engineering Department is leading a project to develop a novel autonomous microrover, weighing in at nearly one kilogram and powered by an advanced microbial fuel cell (MFC) technology.

"The goal is to demonstrate a more efficient and reliable energy source for use in powering small robotic vehicles in environments where the option for human intervention is nonexistent," said Scott. "Microbial fuel cells coupled with extremely low-power electronics and a low energy requirement for mobility addresses gaps in power technology applicable to all robotic systems, especially planetary robotics."

The MFC was selected because of its long-term durability owing to the ability of microorganisms to reproduce and the bacterium's high energy density compared with traditional lithium-ion power sources. This research explores in more detail the use of microbes as a power source and moves to eliminate



Electron microscope image of the microbe *Geobacter sulfurreducens*, the core of the microbial fuel cell based system.

Initial artistic concept of a low-power microrobotic system that could be a test bed for the microbial fuel cell power system and onboard electronics being developed as part of this project. Both walking and hopping locomotion are being investigated for the prototype system.

the existing bulk associated with MFC infrastructure, such as large, power-intensive pump systems and MFC mass and volume requirements.

A portion of the energy generated by the MFC will be used to maintain onboard electronics and control systems, with the remaining energy directed toward slowly charging a battery or capacitor until a sufficient amount of electricity is collected.

“ The goal is to demonstrate a more efficient and reliable energy source for use in powering small robotic vehicles in environments where the option for human intervention is nonexistent ”

Once sufficient power is stored, the system can then discharge this collected energy to activate a more power-intensive scientific instrument or to propel the rover forward using a novel tumbling or hopping locomotion system.

Focusing on a pure culture anaerobic bacterium, such as *Geobacter sulfurreducens*, as the core of the microbial fuel cell based system, the power generation technology for this research would have an exceptionally long lifetime, beneficial for recharging onboard batteries or capacitors and providing for long-duration scouting missions.

“As we move forward in the utilization of MFCs as an energy generation method, this research begins to lay the groundwork for low-powered electronics with a long-term potential for space and robotic applications,” adds Scott.

Through his selection as a Fellow to the newly reinstated NASA Innovative Advanced Concepts (NIAC) program, Scott was awarded a research grant to investigate the initial phase of this innovative concept.

The Low Power Microrobotics project combines three areas of research. Locomotion system development is led by Dr. Gregory P. Scott, the project's principal investigator, who is also responsible for overall system concept and subsystem integration. Power system development is led by Dr. Leonard Tender of the Center for Bio/Molecular Science and Engineering, who is building on his team's microbial fuel cell research to develop a smaller and pumpless pure culture MFC. Control system development is led by Dr. Stephen Arnold of the Spacecraft Engineering Department, who is focusing on the system electronics and minimizing the system's power requirements while effectively distributing power to the locomotion system and onboard sensors.

NAVY's Electromagnetic RAILGUN Reaches Testing Milestone

Without the need for dangerous explosives storage and handling, the electromagnetic railgun can potentially reach targets 20 times farther than conventional weapons.

The Naval Research Laboratory Materials Testing Facility demonstrated on October 31, 2011, the one-thousandth successful firing of its electromagnetic railgun, reaching a materials testing milestone in the weapon's technological development and future implementation aboard U.S. Navy warships.

"This test demonstrates continued advances in armature development, rail design, and barrel materials used in high power railgun launch," said Dr. Robert Meger, head of the NRL Charged Particle Physics Branch. "Firing up to 15 shots per week on the laboratory's experimental railgun, researchers at NRL perform detailed testing and analysis of rails and armatures, providing S&T expertise to the Navy program that is directly applicable to tests at large-scale power levels."

Many of the 1000 shots taken on the Materials Testing Facility railgun have been designed to test different barrel designs and to quantify damage generated during high power launch. The innovations and understanding generated by NRL's science and technology (S&T) program have been fed directly into the Office of Naval Research's Electromagnetic Railgun program and transferred to full-scale tests conducted at the Naval Surface Warfare Center, Dahlgren, Virginia.

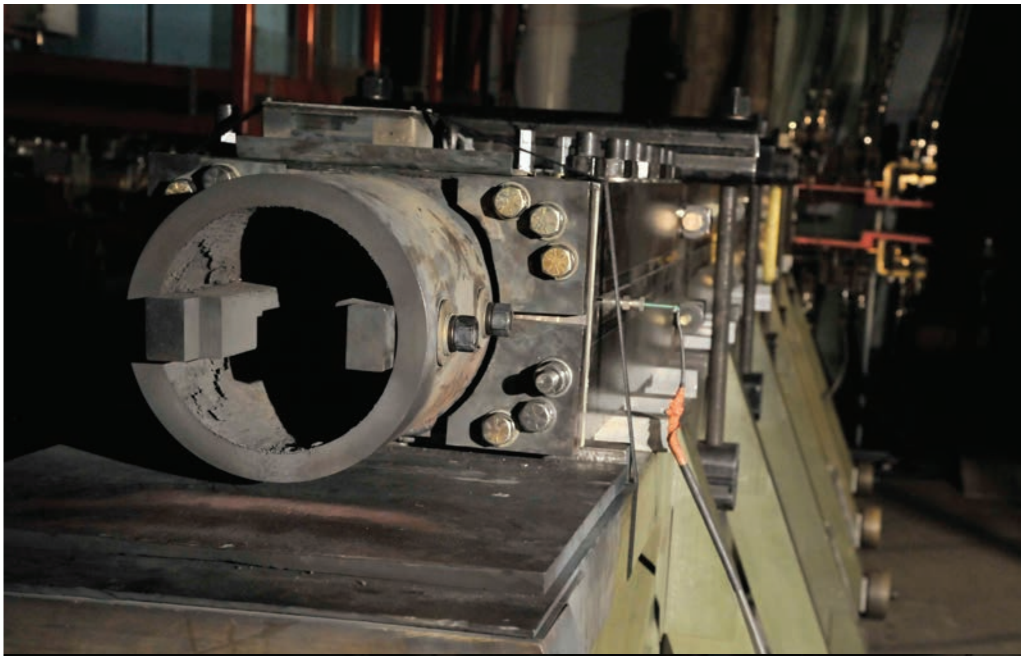
A railgun is a form of single turn linear motor. Magnetic fields generated by high currents driven in parallel conductors, rails, accelerate a sliding conductor, known as an armature, between the rails. The velocity generated by the system is limited by rail strength and armature materials and their response to the high currents and extreme pressures generated during launch.

At launch, heat deposited in the armature and near the surface of the rails due to high currents and friction, or viscous heating generated at the sliding interface, leads to temperatures sufficient to melt most metals including the armature material. If the heating and extreme pressures also damage the rail surface, it can destroy the contact surface and condemn the gun barrel. NRL S&T research has pioneered multiple barrel and armature designs that minimize or mitigate this damage even during successive high power launches.

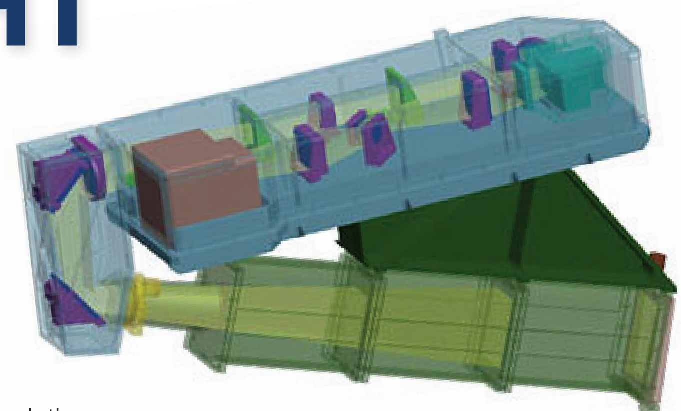
First fired March 6, 2007, at a magnitude of 0.5 megajoules, the railgun system at NRL has been modified and enhanced over the last four years to operate routinely at a 1.5 megajoule launch energy. A megajoule is a measurement of kinetic energy associated with a mass traveling at a certain velocity. In simple terms, a one-ton vehicle moving at 100 mph has approximately one megajoule of kinetic energy.

"A railgun weapons system must be able to launch hundreds of projectiles and withstand extreme pressures, currents, and temperatures," said NRL Commanding Officer, Capt. Paul Stewart. "Today's firing of the one-thousandth shot demonstrates Navy researchers are steadily progressing toward achieving that goal, developing a more effective and efficient future ship combat system."

The Railgun Materials Testing Facility railgun focuses on materials issues for a major Navy effort to develop a long-range, electromagnetic launcher for a future electric ship. The NRL Plasma Physics Division conducts a broad program in laboratory and space plasma physics and related disciplines, high power lasers, pulsed-power sources, intense particle beams, advanced radiation sources, materials processing, and nonlinear dynamics.



NRL's MIGHTI SELECTED by NASA for POTENTIAL SPACE FLIGHT



Conceptual design of one of the two identical MIGHTI units.

A Naval Research Laboratory instrument designed to study the Earth's thermosphere is part of a future science mission that has been selected by NASA for evaluation for flight.

The NRL-developed Michelson Interferometer for Global High-resolution Thermospheric Imaging (MIGHTI) satellite instrument is part of the Ionospheric Connection Explorer (ICON) mission, led by Thomas Immel at the University of California, Berkeley. The ICON mission will fly instruments designed to understand the extreme variability in our Earth's ionosphere, which can interfere with communications and geo-positioning signals.

Ionospheres act as a boundary between planetary atmospheres and space, containing weakly ionized plasmas that are strongly coupled to their neutral atmospheres, but also influenced by the conditions in the space environment. They experience a constant tug-of-war between these external and internal influences, and exhibit a remarkable set of nonlinear behaviors. The unpredictable variability of the Earth's ionosphere interferes with communications and geo-positioning signals and is a national concern. ICON makes a complete set of measurements of the state of the ionosphere and all of the critical drivers that affect it to understand this variability.

NRL's MIGHTI instrument will contribute to reaching the mission goals by measuring the neutral winds and temperatures in the Earth's low latitude thermosphere. The MIGHTI instrument uses the DASH (Doppler Asymmetric Spatial Heterodyne spectroscopy) technique, which was co-invented and pioneered by NRL. The payload consists of two identical units that will observe the Earth's thermosphere with perpendicular viewing directions. As ICON travels eastward and continuously images the thermosphere and ionosphere, MIGHTI will measure the vector components of the vertical wind profile.

NRL's MIGHTI is named for Albert Michelson, a physicist known for his research on the measurement of the speed of light using a related interferometer type. More directly, MIGHTI builds on technology previously used in NRL's SHIMMER (Spatial Heterodyne Imager for Mesospheric Radicals), a payload aboard STPSat-1.

The ICON mission proposal, that NRL's MIGHTI is a part of, is one of five proposals selected for Explorer Missions. With its selection for further evaluation, the NRL MIGHTI team, led by Dr. Christoph R. Englert, NRL's Space Science Division, will receive NASA funding and work for 11 months to further develop the MIGHTI concept. Subsequently, NASA will select up to two of the Explorer Mission proposals to proceed toward flight, with launches expected as early as 2016.

NRL Hosts The First Annual Karles Invitational Conference



On August 15 and 16, 2011, the Naval Research Laboratory hosted the first annual Karles Invitational Conference, named in honor of Dr. Jerome Karle, 1985 Nobel Laureate in Chemistry, and Dr. Isabella Karle, a 1993 Bower Award Laureate and 1995 recipient of the National Medal of Science. The theme of the conference was "Microbial Systems and Synthetic Biology."

The fundamental research of the Karles was critical in elucidating the molecular structure and function of complex macromolecules. The Karles' contributions continue to have a significant impact on the basic and applied physical, chemical, metallurgical, geological, and biological sciences. In commemoration of the Karles' achievements and broad scientific impact, NRL initiated this annual conference to convene the leading authorities and innovators from scientific disciplines that are on the verge of producing contributions with similar reach and impact.

TOP: Dr. Bhakta B. Rath, Dr. David A. Honey, and Dr. John A. Montgomery

MEMBERS OF THE ORGANIZING COMMITTEE: Dr. Bhakta B. Rath, Ms. Anne Kusterbeck, Dr. Banahalli Ratna, and Dr. Gary Vora

The completion of the first decade of research in the fields of microbial systems and synthetic biology has resulted in the development of the tools and methods necessary to make global cellular measurements, integrate these data to map, model, and predict cellular function, and use this systems-level understanding to guide the rational design, construction, and optimization of novel genetically engineered circuits and organisms. As a result of this considerable progress, both fields now lie on the verge of combining to develop transformative bioengineered solutions for recalcitrant problems in energy and biofuel synthesis, environmental remediation, chemical and biological sensing, pharmaceutical synthesis, and materials science. It is this potential that has elicited considerable interest and investment, and has resulted in the prioritization of systems and synthetic biology research in academia, industry, and government.

The NRL conference provided a forum for approximately 150 invited multidisciplinary scientists, sponsors, policy makers, industrialists, and technical society leaders to discuss the challenges, recent breakthroughs, and future of microbial systems and synthetic biology research.

KEYNOTE ADDRESSES

Dr. David Honey
Director of Research of the Office of the Secretary of Defense, Department of Defense, "Department of Defense Science & Technology Planning and Synthetic Biology"

Dr. Subra Suresh
Director of the National Science Foundation, "Probing Human Diseases Across Disciplinary Boundaries"

FEATURED SPEAKERS

Dr. Leroy Hood
Institute for Systems Biology

Dr. Bhakta Rath
Naval Research Laboratory

Dr. Hiroaki Kitano
The Systems Biology Institute

Dr. Pamela Silver
Harvard Medical School

Dr. Bernhard Palsson
University of California, San Diego

Dr. Gary Vora
Naval Research Laboratory

Dr. John Glass
J. Craig Venter Institute

Dr. Drew Endy
Stanford University

Dr. Christopher Voigt
Massachusetts Institute of Technology

Dr. Steven Benner
Foundation for Applied Molecular Evolution

Dr. John Montgomery
Naval Research Laboratory

Dr. Adam Arkin
University of California, Berkeley

Dr. Zach Serber
Amyris

Dr. Arthur Grossman
Solazyme, Carnegie Institution for Science

Dr. Andreas Schirmer
LS9, Inc.

NRL RESEARCHERS discover technique to IMPROVE SOLAR CELL TECHNOLOGY

Drs. Joseph Melinger, Paul Cunningham, Joseph Tischler, and Matthew Lumb next to a two-color femtosecond laser pump-probe apparatus used to measure the efficiency of multiple exciton generation in PbSe semiconductor nanocrystals and nanorods.

Drs. Edward Foos, Janice Boercker, and Anthony Smith in the nanomaterial synthesis laboratory.

A multidisciplinary team of scientists at the Naval Research Laboratory has discovered a way to tailor nanostructures that could result in low-cost, high-efficiency solar cells. The research appears in the August 10, 2011, issue of the journal *Nano Letters*.

The technology behind optoelectronic devices currently in use has been limited by the fact that a single photon absorbed by a semiconductor results in the creation of a single electron-hole pair, or exciton. The NRL researchers have found that changing the shape of PbSe (lead selenide) nanostructures enhances a downconversion process known as multiple exciton generation. To accomplish this, the team uses elongated (cigar-shaped) nanorods instead of spherically symmetric (ball-like) nanocrystals.

Unlike the current optoelectronic technology that relies on a single electron-hole pair per photon, in multiple exciton generation, the excess energy of the "hot" exciton is used to excite a second electron across the band gap resulting in the creation of two or more excitons per photon. The NRL team's discovery that this process is significantly more efficient in the elongated nanorod structures provides a new pathway to increasing the efficiency of solar cells over current state-of-the-art devices.

These elongated structures are the most efficient photon energy downconverters known. As a result, this material system provides a way of harvesting solar energy extremely efficiently. In addition, the synthesis process is low cost, which would make these solar cells very inexpensive, and the materials are compatible with solution processing of devices on flexible substrates. Possible future applications emerging from this technology besides photovoltaic cells could include ultrasensitive photodetectors, high-speed electronics, light emitting diodes, lasers, and biological labels.

The research team consists of Drs. Paul Cunningham, Janice Boercker, Matthew Lumb, Joseph Tischler, and Joseph Melinger from NRL's Electronics Science and Technology Division; and Drs. Edward Foos and Anthony Smith from NRL's Chemistry Division.

NAVY's MODERN AIRSHIP receives Historical Identification

Unveiled at a ceremonious ribbon-cutting event, October 26, 2011, at the Naval Air Warfare Center Aircraft Division (NAWCAD), Lakehurst, New Jersey, NAWCAD and the Naval Research Laboratory revealed the MZ-3A airship now adorned with the insignia of Scientific Development Squadron ONE (VXS-1) and the banner of the U.S. Navy.

"It's been nearly 50 years since the last U.S. Navy Lighter-Than-Air platform cruised the skies over the New Jersey coastline," said CDR Jay Steingold, Commanding Officer, VXS-1. "Today, the MZ-3A joins the ranks of her predecessors by sporting the emblems of the United States Navy, marking an important milestone in the history of naval airships."

After 47 years, the U.S. Navy effectively terminated Lighter-Than-Air (LTA) operations, August 31, 1962, with the final flight of a ZPG-2 airship at Naval Air Station Lakehurst. Emblazoned with red, white, and blue stripes on her rudders acknowledging the Navy's Centennial of Flight and earliest days of Navy airship operations, the MZ-3A boasts a proud heritage and now serves as the only manned airship in the United States Navy's inventory.

Built by American Blimp Corporation, the MZ-3A is propeller-driven by two 180-horsepower Lycoming engines producing a top speed just under 50 knots with an operational payload capability of up to 2,500 pounds.

The manned 178-foot LTA craft can remain aloft and nearly stationary for more than twelve hours, performing various missions in support of technology development for Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR) concepts.

"Airships offer extreme utility in C4ISR roles and patrol missions where persistent stare and reliable communications are often more important than speed," said Bert Race, MZ-3A Government Flight Representative and Project Manager. "Our MZ-3A has proven that an airship is a very effective platform for mission system research and development."

The MZ-3A is government-owned and contractor-operated. The contractor, Integrated Systems Solutions, Inc., employs highly qualified commercial blimp pilots whom the Navy has approved to command the airship.

Scientific Development Squadron ONE (VXS-1), stationed at the Naval Air Station, Patuxent River, Maryland, is the U.S. Navy's sole science and technology research squadron. Commissioned December 2004, VXS-1 employs NP-3D Orions, an RC-12 Huron, a Scan Eagle UAS, and most recently, the MZ-3A in its support of NRL-priority airborne research efforts. Since its transfer to VXS-1 in October 2009, the MZ-3A has accumulated more than 1,000 mishap-free flight hours in support of the Naval Research Enterprise and provided assistance during the Gulf of Mexico oil spill in 2010.

WARLOCKS
VXS-1

A modified American Blimp Corporation A-170 series commercial blimp, the MZ-3A boasts a proud heritage and now serves as the only manned airship in the United States Navy's inventory.

Hart Middle School STUDENTS Sample a Day at NRL

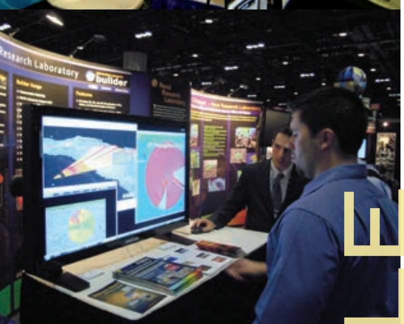
On January 10, 2012, the Naval Research Laboratory hosted a visit of 40 students from Hart Middle School, located in Washington, D.C. The students attended a program sponsored by NRL's Diversity Committee in honor of the Martin Luther King, Jr. holiday. This program featured Ayanna Gregory, daughter of comedian and human rights activist, Dick Gregory. In the auditorium packed with NRL employees and the middle school students, Gregory performed her one-woman program, "Daughter of the Struggle," recreating her inspiring journey as the daughter of a freedom fighter.

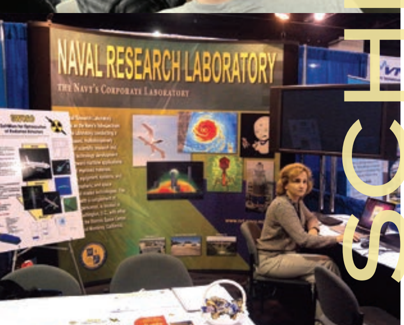
Following the program, the students attended a lunch hosted by the NRL Toastmasters, and took part in a Toastmaster's sample Youth Leadership Program, with student volunteers gaining experience in impromptu speaking before the audience of NRL

Toastmasters. NRLer Lawrence Walker, who attended Hart Middle School, spoke about the importance of being diligent students and making wise choices.

When the Toastmasters meeting was complete, students took part in some hands-on science demos in the Friedman Room, one of NRL's large meeting and display rooms. The students, who are currently working on their own science fair projects, asked questions and bounced their ideas off the scientists who participated. NRL's Vijay Kowtha, who is a mentor at Hart Middle School, arranged the visit. NRL scientists from the Chemistry Division, Tactical Electronic Warfare Division, Spacecraft Engineering Department, and Space Systems Development Department supported the hands-on demos.

NRL ON THE ROAD



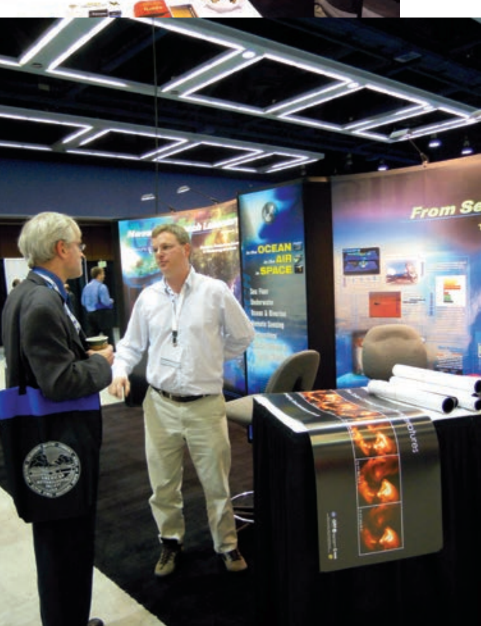


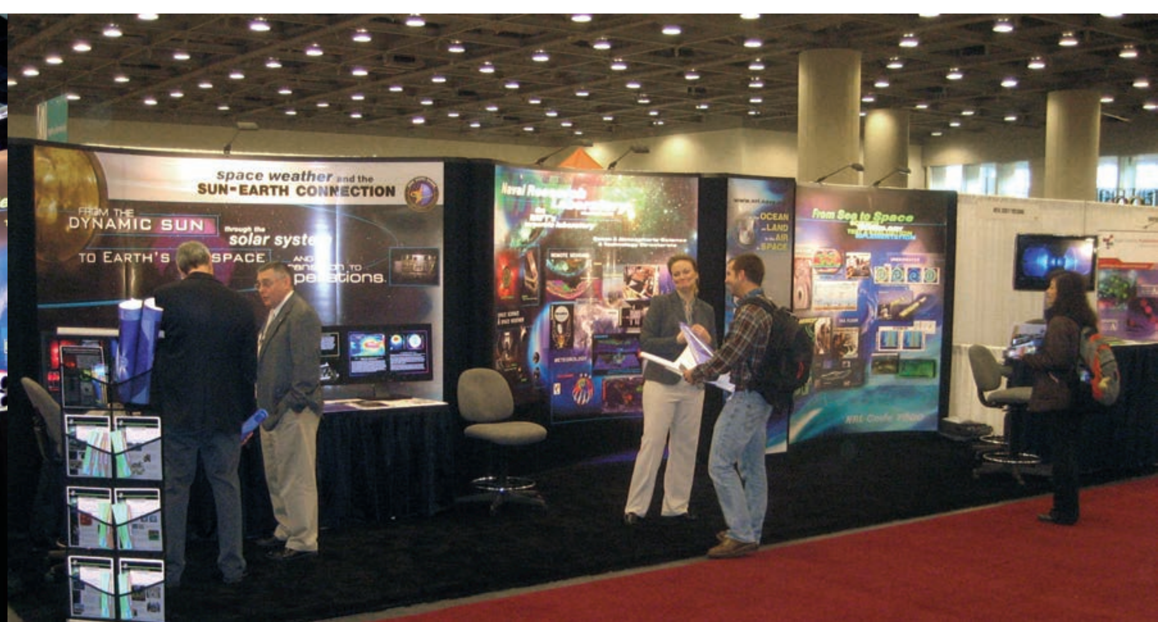
NRL'S EXHIBIT PROGRAM

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 nontraditional audiences and excite visitors with interactive displays, models, artifacts, presentations, and participatory demonstrations.

SCHEDULE

2012 Ocean Sciences Meeting	February 20–24, 2012	Salt Lake City, UT
2012 Joint CBRN Conference and Exhibition	March 12–14, 2012	Baltimore, MD
National Space Symposium	April 16–19, 2012	Colorado Springs, CO
Navy League – Sea Air Space	April 16–18, 2012	National Harbor, MD
USA Science and Engineering Festival	April 28–29, 2012	Washington, DC
2012 IEEE Symposium on Radiation Measurements & Applications	May 14–17, 2012	Oakland, CA
International Hazardous Materials Response Teams Conference	May 17–20, 2012	Baltimore, MD
38th IEEE Photovoltaic Specialists Conference	June 3–8, 2012	Austin, TX
AUVSI	August 6–9, 2012	Las Vegas, NV
Association of Old Crows International Symposium	September 23–26, 2012	Phoenix, AZ





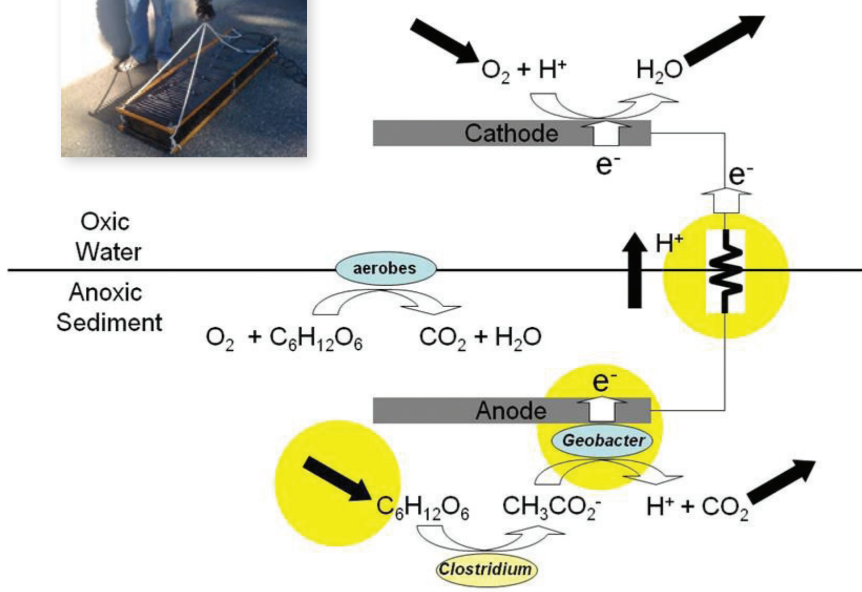
TECHNOLOGY TRANSFER OFFICE

NRL's Technology Transfer Office (TTO) facilitates the implementation of NRL's innovative technologies in products and services to benefit the public. Detailed here is one of many technologies available for licensing.

BENTHIC MICROBIAL FUEL CELL

Persistent power supply for in-water sensors

The Naval Research Laboratory has developed the benthic microbial fuel cell (BMFC) as a persistent power supply for marine-deployed applications requiring up to 1 watt time-average power. The BMFC operates on the bottom of marine environments where it oxidizes organic matter residing in sediment with oxygen in overlying water. The NRL BMFC is a maintenance-free, nondepleting power supply suitable for a wide range of sensors presently powered by batteries. Unlike batteries, however, the NRL BMFC will not deplete, owing to constant supply of its fuel and oxidant by environmental processes and constant rejuvenation of its microbial electrode catalysts. For this reason, the NRL BMFC is an ideal power supply when long-duration, uninterrupted sensor operation is a must, and for hard-to-access sensors and high-density sensor arrays for which the cost of battery replacement is high.



Advantages/Features:

- Low cost
- Durable and efficient electrodes
- No moving parts
- No consumable components

Applications:

- Marine-deployed naval and scientific instruments

References

"The First Demonstration of a Microbial Fuel Cell as a Viable Power Supply: Powering a Meteorological Buoy," *Journal of Power Sources* 179 (2008) 571–575.

U.S. Patent 6,913,854, "Method and Apparatus for Generating Power from Voltage Gradients at Sediment-Water Interfaces."

See also these new technologies available for licensing:

- Cell and biofactor printable biopapers
- Small, high efficiency, recuperated ceramic turboshaft engine
- Metallized nanotextured thin films for sensing and catalyst applications
- Chembio sensor: porous electrode, vertical nanowire

Contact the Technology Transfer Office:
(202) 767-7230
techtran@research.nrl.navy.mil
http://www.nrl.navy.mil/techtransfer

Dr. Jeffrey Book receives *Presidential Award* for Career Achievements

President Barack Obama greets the 2010 recipients of the Presidential Early Career Award for Scientists and Engineers in the East Room of the White House, Oct. 14, 2011. (Official White House Photo by Pete Souza)

Dr. Jeffrey Book in the Naval Research Laboratory's Oceanography Division has been awarded the highest honor bestowed by the U.S. government on scientists and engineering professionals in the early stages of their independent research careers, the Presidential Early Career Award for Scientists and Engineers.

The Presidential Early Career Award for Scientists and Engineers

Dr. Book traveled to Washington, D.C., to attend a recognition ceremony led by the White House Office of Science and Technology Policy. Of the 94 awardees, Dr. Book was the sole Department of the Navy recipient.

In the Physical Oceanographic Processes Section at Stennis Space Center, Mississippi, Dr. Book serves as principal investigator for a new NRL project, oceanographic lead for two ongoing NRL projects, and co-investigator on a fourth project.

As principal investigator for the Dynamics of the Adriatic in Real Time (DART) project, Dr. Book's research has led to scientists' improved understanding of ocean circulation in shallow, topographically complex areas and the ability to predict the environment there. Together with the NATO Undersea Research Center and other NRL scientists, Dr. Book worked on the development of new oceanographic instrumentation for ocean monitoring, specifically SEPTR, the shallow-water environmental profiler in trawl-safe real-time configuration, that has now successfully been used to collect more than 600 profiles of oceanic data for scientific use.

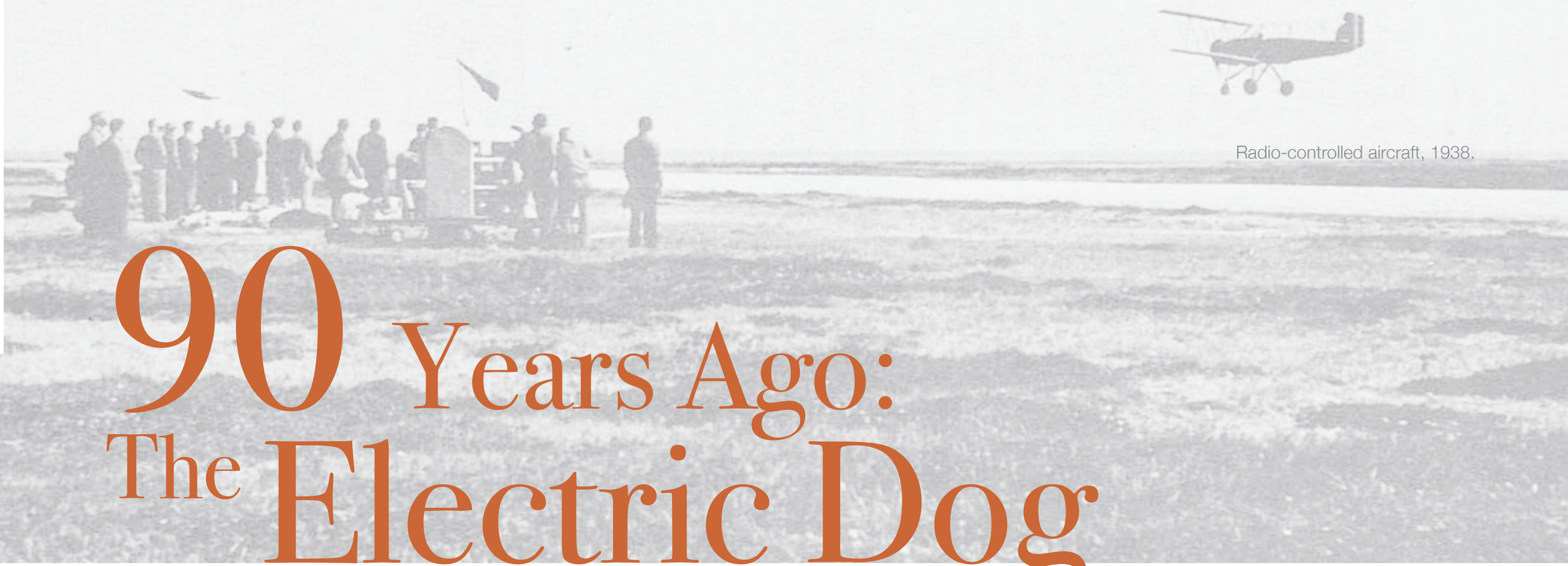
Dr. Book is also the oceanographic lead on a groundbreaking research project that uses seismic oceanography to provide high-resolution measurements of ocean temperature layers for studying ocean mixing. "Dr. Book's visionary research may lead to a revolutionary high-resolution oceanographic measurement technique," said Dr. Ruth Preller, superintendent of NRL's Oceanography Division.

As co-investigator for the NRL project Environmental Optimization of Sea-Bed Energy Harvesting for Navy Devices, Dr. Book is working to use renewable energy to power underwater oceanographic equipment using benthic microbial fuel cells, which make use of the oxygen difference across the ocean sediment/water interface and biochemical energy derived from organic material in the sediment.

"I am very honored to receive this award. Many scientists at NRL and around the world have been very gracious to me as a young scientist with their time and experience and I am deeply appreciative of the support and guidance that they have given me."

Dr. Book received a bachelor's degree in physics from University of Missouri-Rolla and a master's degree and a Ph.D. from the University of Rhode Island Graduate School of Oceanography.

Photo from A. Hoyt Taylor, *The First 25 Years of the Naval Research Laboratory* (Navy Department, Washington, DC, 1948), p.49.

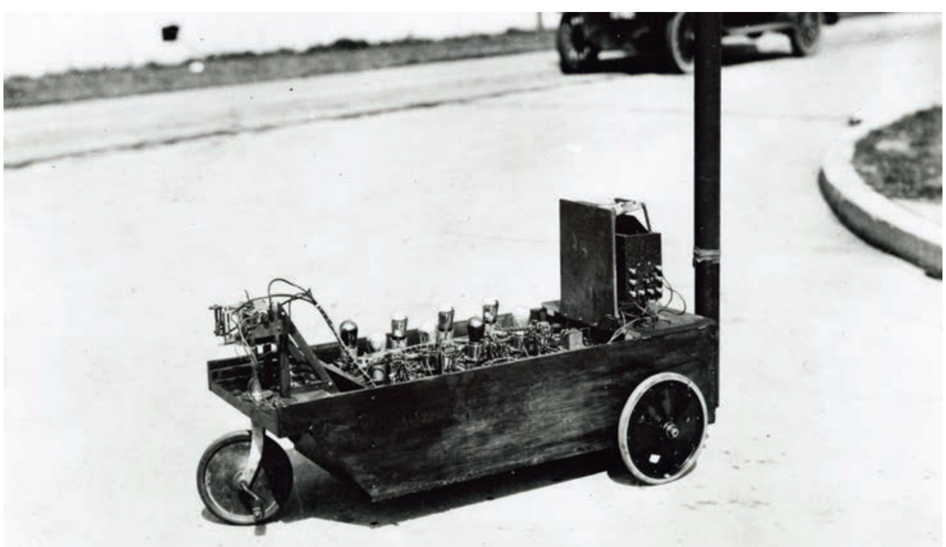


Radio-controlled aircraft, 1938.

90 Years Ago: The Electric Dog

The Naval Research Laboratory turns 89 this year, but its first unmanned system got its start 90 years ago.

In 1922, at the Anacostia Naval Aircraft Radio Laboratory, engineer Carlos B. Mirick was developing a system for radio remote control of aircraft. When NRL opened in 1923, Mirick and the others at Anacostia transferred to become part of the new NRL Radio Division. Mirick continued his work and built the "electric dog" unmanned ground vehicle to test his remote-control system.



A. Hoyt Taylor, who had been head of the Anacostia laboratory and became the first superintendent of the NRL Radio Division, recalled, "In 1922 Mr. C. B. Mirick started work on pilotless target planes, known as 'drones'. To those who know anything about honey bees, the significance of the term will be clear. The drone has one happy flight and then dies. I believe I am responsible for this name for pilotless target planes."

"The work on radio controlled pilotless airplanes [that] started at Anacostia was continued, under Mr. C. B. Mirick, at the Naval Research Laboratory. In the winter of 1923-1924, Mirick tested his various radio control devices by the use of a small three-wheeled cart which came to be dubbed the 'electric dog'."

Mirick described his vehicle in a 1946 article: "The front wheel of this cart was improvised from a small boy's velocipede and still retained pedals which gave the contraption a somewhat jaunty air. Within the past year pictures of this equipment have been broken out and Mr. Robert E. Luke, son of Lieutenant Commander E. L. Luke, and now a radio engineer at the NRL, remarked rather bitterly, 'Yes, that was *my* velocipede.' The cart was driven by small series motors supplied from a storage battery. It is of possible interest that the control switch for operating this device consisted of a small vertical stick similar in action to the control stick of an airplane. The four circuits controlling the cart were connected for forward, reverse, right turn, and left turn. In principle, this control stick was almost identical with that employed in recent German radio-controlled missiles. At intervals during this winter, the 'dog' wandered slowly and somewhat uncertainly about in driveways at the Naval Research Laboratory but it did demonstrate a successful simultaneous and independent operation of control circuits."

Quote sources: A. Hoyt Taylor, *Radio Reminiscences: A Half Century* (Naval Research Laboratory, 1948, 1960); and C. B. Mirick, "A Wild-Goose Chase: Early Navy Work on Pilotless Aircraft and Ships," *U.S. Naval Institute Proceedings*, July 1946, p. 947–951.

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RN: 12-1231-0711
March 2012
CAPT Paul C. Stewart
Commanding Officer