ONR
INNOVATION
OFFICE OF NAVAL RESEARCH VOL. 8 | SPRING 2012


# ENABLING THE GREAT GREEN FLEET

# LETTER FROM THE NEW CHIEF OF NAVAL RESEARCH

**Chief of Naval Research Matthew Klunder kicks off the afternoon round of Rebound Rumble during the FIRST (For Inspiration and Recognition of Science and Technology) Robotics Competition being held at the Washington Convention Center in Washington, D.C. FIRST combines the excitement of sports with the rigors of science and technology where teams of high school students design, build and program robots to perform prescribed tasks against a field of competitors. (U.S. Navy photo by John F. Williams/Released)**

***RADM Matt Klunder***

Our Navy continues to deploy new innovative vehicles, vessels, and aircraft that make today's systems more effective and affordable and tomorrow's a leap ahead from our current capabilities. This diverse fleet of systems and platforms requires efficient power sources to operate optimally and affordably. Here at ONR, we are focused on three key characteristics of energy systems to meet the needs of our future Fleet and Force: Mobile, Maritime, and Affordable.

The Navy uses 75% of its energy afloat, creating a unique need for energy sources that are both efficient AND portable. This demand for mobility is often not met by current, commercially-viable energy solutions. Our challenge is to develop new methods for conversion, distribution and control to meet the Fleet and Force power demands for light-weight and low volume systems.

## IN THIS ISSUE

Not only are the Navy and Marine Corps mobile, but we operate in some of the harshest, most complex environments. Bottom line: future power systems must be able to operate reliably and safely wherever our Sailors or Marines are found. Whether at sea, in the air, on the ground or in space, we must be able to rely on the new energy sources to support and power us through any mission.

Energy plays a large role in our operational and national security vulnerabilities, so the Office of Naval Research continues to invest in this vital area even as budgets shrink across the Department of Defense. When we invest in our future energy systems, we must consider total ownership costs when making investment decisions to ensure that initial costs are weighed against warfighting enhancements.

We have a responsibility here at ONR and across the Naval Research Enterprise to ensure that our Warfighters never face a day when they cannot carry out their missions because they don't have the energy resources they need. Every Department at ONR is working on a piece of the energy challenge and our partners throughout the Navy are working too. Together I am confident that we will make the type of progress we need, meeting the challenges of energy head on.

I look forward to working with you toward this important goal. ■

# NAVY ENERGY

## 2016

"By 2016, the Navy will sail the Great Green Fleet, a carrier strike group composed of nuclear ships, hybrid electric ships running biofuel, and aircraft flying on biofuel."

– The Honorable Ray Mabus, Secretary of the Navy, January 2010

## 2,600

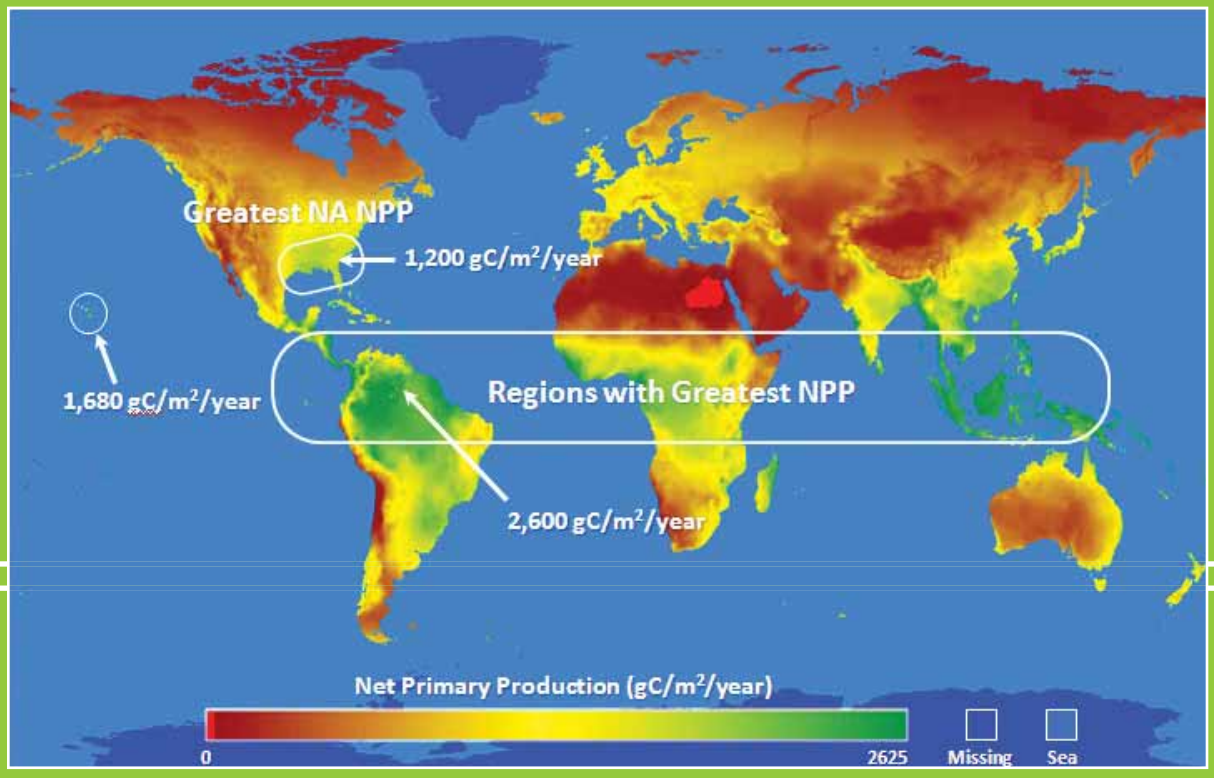
gC/m²/year*

The ability to produce biofuels is directly impacted by the production capacity of land. Net primary production (NPP) is a calculation based on the natural amount of sunlight, temperature, and precipitation (and their distribution throughout the year) in a region. The regions of the world with the greatest NPP are in the tropics. The continental U.S. region with the greatest NPP is in the southeast. The amount of natural NPP in Brazil is more than twice that of the southeastern U.S. This is a significant reason why the Brazilians can produce more biofuels than the U.S.

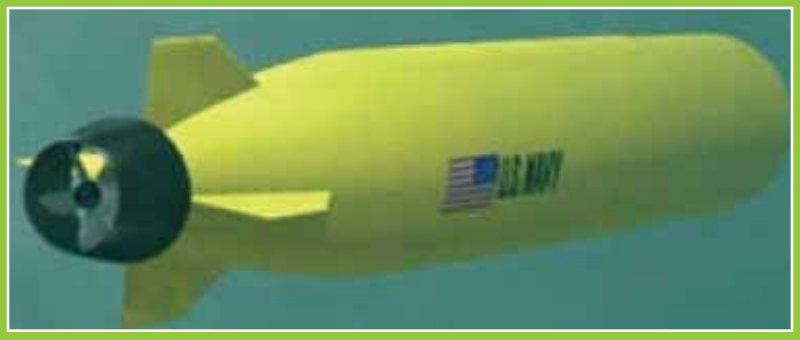
## 2025

The goal of the Marine Corps is to reduce battlefield requirements for energy by 50% by 2025; and 50% of bases and stations will be net-zero energy consumers by 2020.

–General James F. Amos, Commandant of the Marine Corps, March 2011




* gC/m²/year—grams of carbon per square meter per year



# 90 DAYS

The goal of the Large Displacement Unmanned Undersea Vehicle (LDUUV) Innovative Naval Prototype (INP) is to provide the Navy with the increased capability of powering unmanned UUVs for a 60-90 day period. The program is trying to achieve the same endurance as our buoyancy driven UUVs (i.e., gliders) with propeller driven power. This would be a huge breakthrough for propeller driven UUVs as the current state of the art is just over one week.

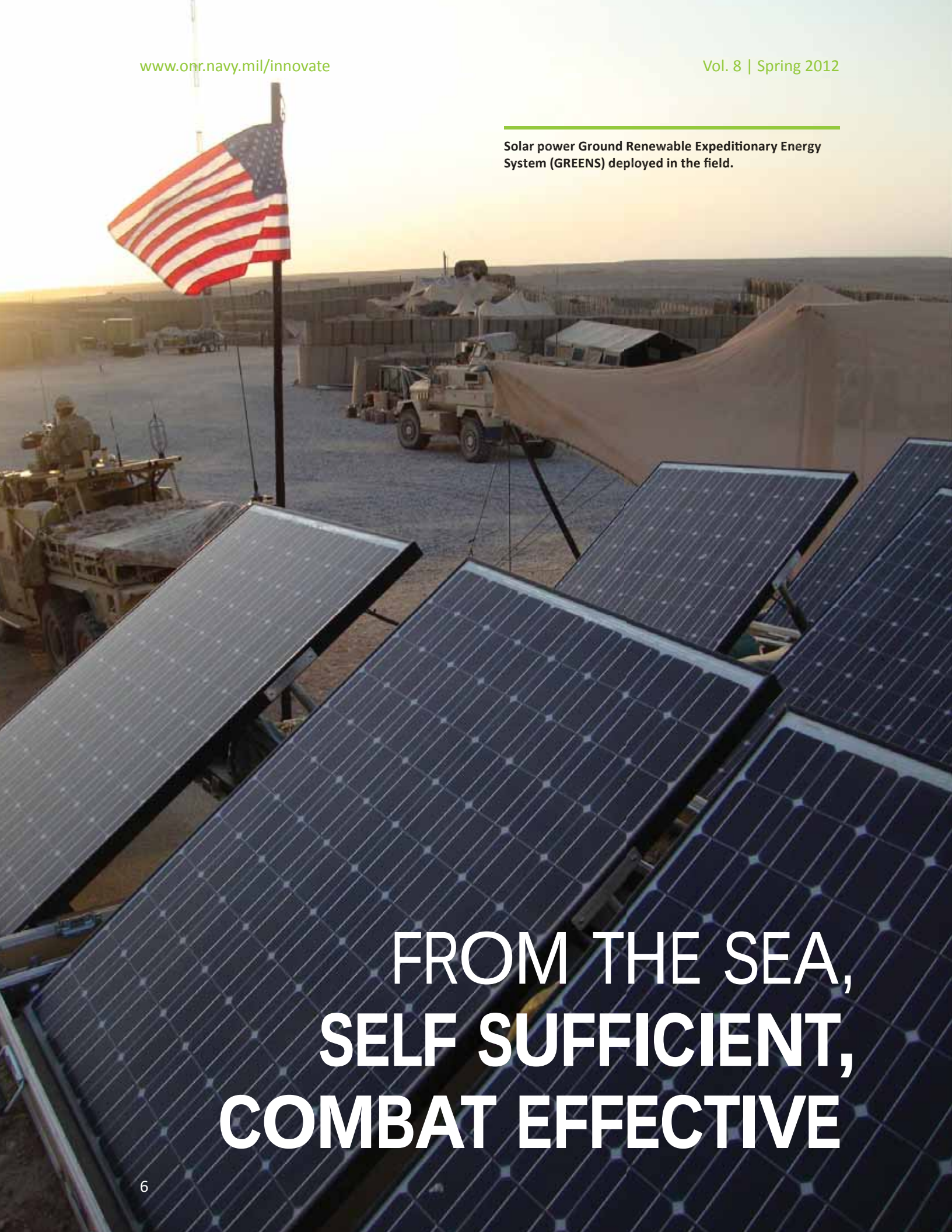
# 0

The eventual goal of Navy SEALs deploying this summer is net-zero energy and net-zero water. "They're going to use flexible generators that are many times more efficient than the generators we're using today. They're using portable solar battery chargers, portable solar rays, and highly portable water purification units," according to Secretary Mabus at the Navy Energy Forum, October 2011.

# 50-50

Last September, the U.S. Navy flight demonstration team, the Blue Angels, conducted demonstration flights with a 50-50 mix of biofuel and JP-5 aviation fuel.

# NUMBERS AND FACTS



Solar power Ground Renewable Expeditionary Energy System (GREENS) deployed in the field.

# FROM THE SEA, **SELF SUFFICIENT, COMBAT EFFECTIVE**

# HOW THE MARINES ARE INTEGRATING RENEWABLE ENERGY TECHNOLOGY INTO THE FUTURE FORCE

***Ms. Gayle Von Eckartsberg***, Deputy Director, Expeditionary Energy Office, U.S. Marine Corps

"To a Marine, the term 'Expeditionary' is more than a slogan; it is our state of mind. It drives the way we organize our forces, how we train, and what kind of equipment we buy." In March 2011, at the same time the Commandant of the Marine Corps, General James Amos, made this statement, the Marine Corps and the Office of Naval Research (ONR) were moving out to deploy renewable energy capabilities to Marines operating at the very edge of the battlefield in Afghanistan. The objective: equip a lighter, more energy efficient force, which would go farther, stay longer, at less risk.

Prototypes of the ONR-funded solar power Ground Renewable Expeditionary Energy System (GREENS) deployed in early 2011, with India Company, 3rd Battalion, 5th Marine regiment. Operating under nearly constant combat conditions in the Sangin valley, the Marines put the equipment to work; they reduced their risk profile by powering two patrol bases entirely on renewable energy, and reduced a Company's COP fuel demand by over 80%. "With the right amount of panels, that [GREENS] system will power everything we need," said India 3/5's first Lieutenant Josef Patterson. "I was a little skeptical at first, that this is something new we have to try out, but I'm completely sold on it. I think it's a great thing."

Power is an enduring requirement on the battlefield, but since 2001, the demand for energy has grown exponentially. Driving this curve are new capabilities Marines have brought to bear on the enemy: a more than 300% increase in the number of computers, a 250% increase in the number of radios, a 200% increase in the number of vehicles, a 75% increase in vehicle weight due to greater armor, and a decrease of 30% in miles per gallon for vehicles across the fleet. As a result, the Marine Corps consumes upwards of 200,000 gallons of fuel daily in Afghanistan. The unintended consequences: increased reliance on fuel resupply, tethering of Marine operations, and increased risk. According to a 2010 study, one Marine is killed or wounded for every 50 fuel and water convoys.

**GREENS deployed in early 2011, with India Company, 3rd Battalion, 5th Marine regiment.**

The Marine Corps is about combat effectiveness. For the Marines, the promise of renewable and hybrid energy is its value to expeditionary operations. Capabilities that reduce the logistics requirement, that allow forces to better fit on ships, that enable warfighters to operate longer and go further when ashore, add up to a more combat effective force.

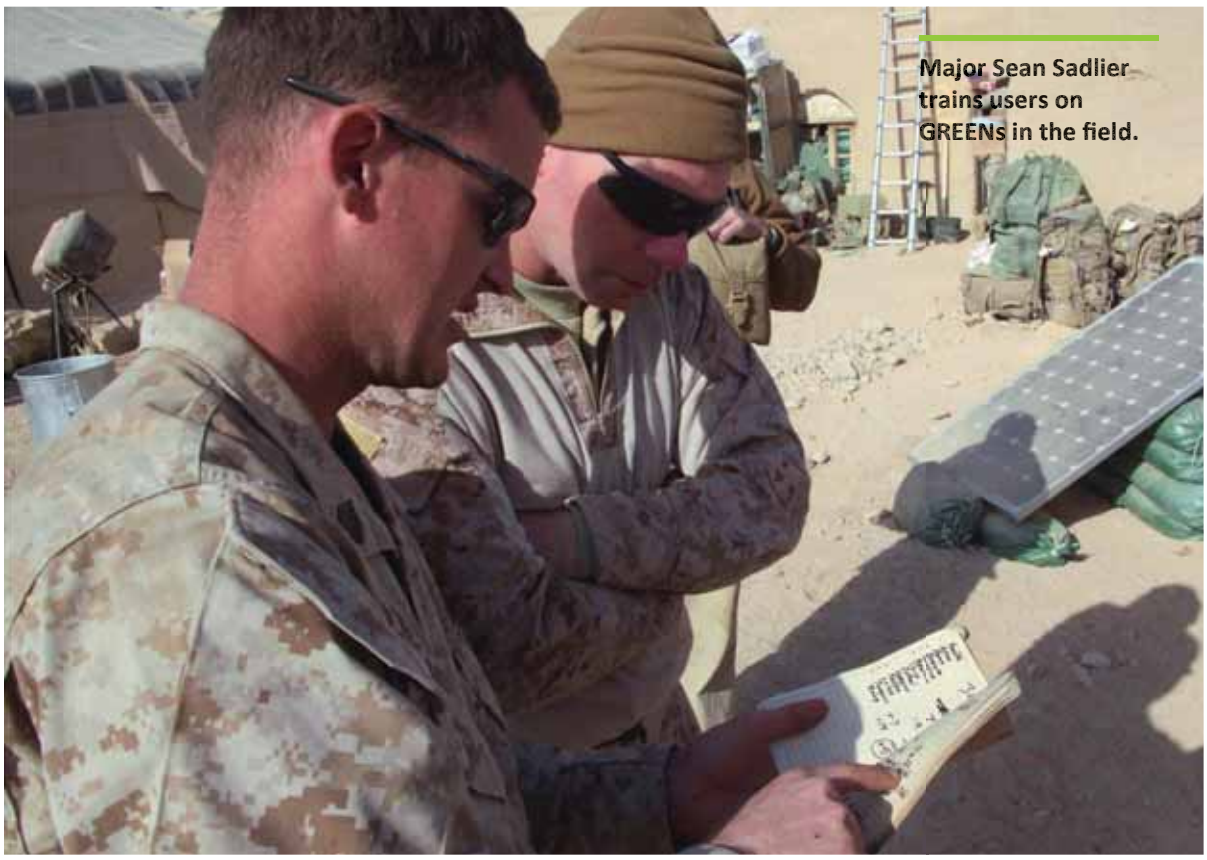
## GREENS HAD THE POTENTIAL TO FIT THE BILL

In 2009, the Commandant of the Marine Corps jumpstarted the expeditionary energy program, and created the Experimental Forward Operating Base process, or ExFOB. By focusing the attention of key players across the Marine Corps and Naval Research enterprise, ExFOB moved the prototype system from test, through end user evaluation in CONUS and in theater, to requirements development and into acquisition in less than two years. In Spring 2011, feedback from India Company 3/5 influenced the Marine Corps to accelerate deployment of GREENS to five battalions in theater. The first production systems were deployed in December 2011, with more than 100 systems on track to deploy by March 2012.

This rapid transition from prototype to program of record required intense collaboration from ONR, Naval Surface Warfare Center Carderock, Marine Corps System Command, Marine Corps Warfighting Lab, Marine Corps Combat Development Command, and the Marine Corps Expeditionary Energy Office.

Developed and tested by Naval Surface Warfare Center Carderock, GREENS harvests energy through the sun using a man-portable array of solar panels and storage batteries to provide an average of continuous output of 300 Watts—the power needed to support small Marine combat outposts, artillery, and radio and surveillance systems, or other demands at the forward edge. Naval Air Warfare Center Weapons Division at China Lake assessed the final prototype, subjecting it to continuous power testing in temperatures exceeding 116 degrees Fahrenheit. Even under these conditions, GREENS worked at 85 percent capacity.

“Systems like this allow [Marines] to charge rechargeable batteries and wean away



**Major Sean Sadlier trains users on GREENs in the field.**

from throw-away, one time use batteries, which greatly reduces weight and resupply requirements," said Justin Govar, the team leader for Advanced Power with Marine Corps Systems Command in an interview with the Marine Corps Base Camp Lejeune Public Affairs Office.

*"Infantry battalions that are far forward do not have immediate access to a wide range of logistics and maintenance equipment; therefore, any source of power that requires no [military-grade fuel], low maintenance and no special skills to operate becomes an instant success. GREENS is modular, portable, rugged and intuitive enough to deploy in a combat environment. Units trained on GREENS as part of pre-deployment training have provided positive feedback."*

— Major Sean Sadlier, a logistics analyst with the Marine Corps Expeditionary Energy Office, who trained users on and tested GREENS in the field with India Company 3/5.

## WHAT'S NEXT?

This year, the Commandant identified expeditionary energy as one of the six "critical" pillars of modernization for the Marine Corps. The mission of the Marine Corps Expeditionary Energy Strategy provides a compelling target for future investment: "By 2025, we will deploy Marine Expeditionary Forces that can maneuver from the sea and sustain C4I and life support systems in place; the only liquid fuel needed will be for mobility systems which will be more efficient than systems are today." To achieve this will require investment not only in procurement, but in science and technology. The Expeditionary Energy Water and Waste Initial Capabilities Document (ICD), approved in September 2011, together with Marine Corps Science and Technology Objectives released in January 2012 provides the roadmap. Priorities include expeditionary energy harvesting, temperature-independent electronics, and optimized personnel performance as well as energy storage other than liquid, expeditionary water harvesting, and energy efficient, combat effective mobility.

For the Marine Corps, the focus remains intensely on power and energy capabilities that make for a lighter, faster, and more austere fighting force—the keys to the expeditionary future force. ■

# JP-5 & F-76

JP-5 and F-76 are Navy unique fuels that have demonstrated durability in the maritime environment. The maritime environment brings unique challenges to fuel and to the development of biofuels, with significant testing and evaluation necessary to ensure the fuel can withstand the Navy environment—specific challenges such as saltwater, handling, and storage life.

## NUMBERS

# MICROBE POWER!

***Linda A. Chrisey, Ph.D,*** ONR Program Officer,
Naval Biosciences and Biocentric Technologies

For the past dozen years, the Office of Naval Research (ONR) has been supporting basic and applied research to understand and develop microbial fuel cells for various underwater and terrestrial applications. Although amongst the smallest organisms on the planet, the discovery that certain bacteria can sustainably generate electricity is big news.

## WHAT IS A MICROBIAL FUEL CELL?

A microbial fuel cell (MFC) is a novel, "green" approach for generating electricity that ONR is developing for the persistent powering of undersea devices. Like conventional fuel cells, MFCs have two electrodes (an anode and a cathode) which are wired to allow the flow of electrical current. However, MFCs are special in that they use microbes as catalysts for generating electricity instead of chemical reactants.

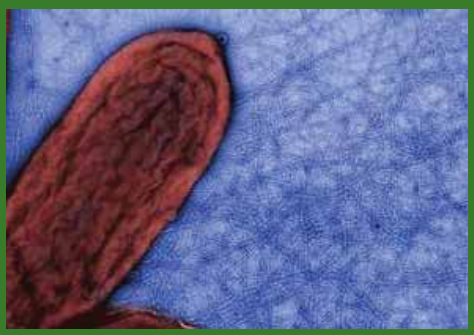
## WHAT ARE "ELECTRICIGENIC" MICROBES?

Nature is often a source of inspiration for new science and technology (S&T). Over millions of years of evolution, organisms have adapted to the many unique environments that exist on our planet. A special class of bacteria known as metal-reducers, actually respire on minerals that include metal oxides and sulfate. These microbes consume organic molecules for fuel and generate electrons which are transferred to the mineral. In 1999, ONR-funded scientists discovered these bacteria could transfer electrons to an electrode. When wired in a circuit with a cathode, small amounts of electrical current were produced and could be used to power various devices.

Geobacter and Shewenella are two key electricity-generating bacteria that ONR is studying. Elucidating the physiology and genetics that allows them to produce electricity may lead to optimized MFC's for practical powering of devices.

## WHAT DOES A MICROBIAL FUEL CELL LOOK LIKE?

ONR is exploring two types of MFCs in its program: chambered and sediment. Chambered MFCs resembles conventional fuel cells in that there are anode and cathode chambers filled with an electrolyte, with a proton-exchange membrane separating the two chambers. Chambered MFCs have been used to power small portable generators, desalination systems, and wastewater treatment systems. The Department of Defense is exploring MFC-like approaches for wastewater treatment to attain energy-neutral, or possibly energy-positive processes, in order to help minimize logistically costly diesel fuel use at Forward Operating Bases.



**(top) False-color image of Geobacter showing pilin (nanowire) network. Credit: PI Lovley, UMASS-Amherst. (bottom) Shewanella oneidensis strain MR-1 growing on hematite. Credit: Pacific Northwest National Laboratory.**

The sediment MFC (see schematic at right) has been the primary focus of the ONR program, as it presents unique opportunities for powering devices underwater. The anode is typically buried in the seafloor sediment to protect it from oxygen, whereas the cathode floats in the water column. Sediment organic matter is the "fuel" used by the MFC to produce electricity as this organic matter is continuously renewed through natural processes; thus, MFCs are sustainable energy harvesting systems. Because the power density is low, power management systems have been designed to store the electricity produced, to convert the MFC power to usable voltages, and to minimize the power needed to bootstrap and run devices.

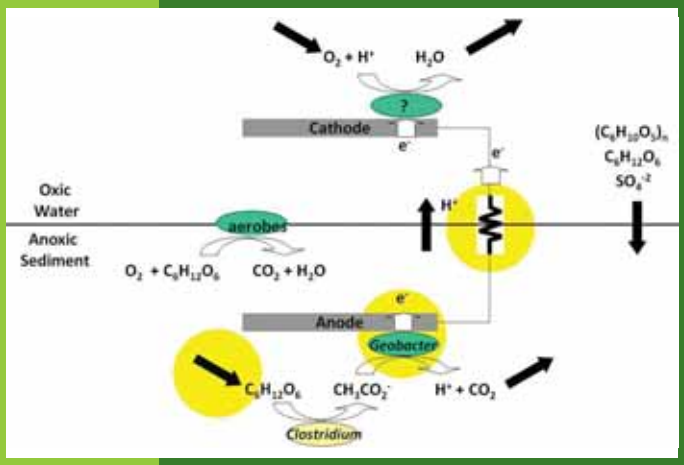
## WHY USE MFCS AND NOT CONVENTIONAL BATTERIES?

Microbial fuel cell technology offers an alternative to seawater batteries which have a finite lifetime and can involve hazardous reactants or products (e.g., lithium, hydrogen). Because MFCs require only renewable organic fuel and can generate electricity directly, they provide a route to safe and persistent power in the undersea environment. Seawater batteries provide approximately 100 W·hours/L—a finite lifetime that depends on the power consumption rate. MFCs provide lower but persistent power (approximately 0.05 W/L). At this power level, the seawater battery would die after 12 weeks whereas the MFC would continue to function. Studies have shown MFCs can continuously provide power for over three years. MFC's have successfully powered acoustic pingers, hydrophones, acoustic vector sensors, underwater modems and environmental sensors (such as oxygen, temperature, and conductivity sensors).

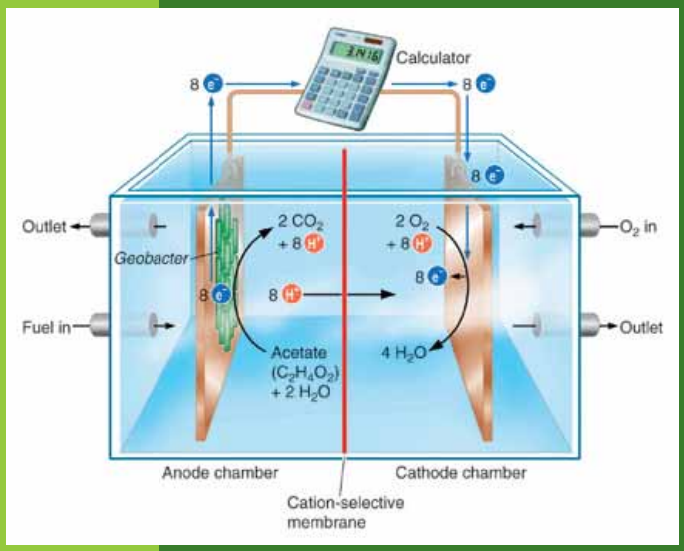
## HOW WILL THE NAVY USE MFCS?

Current field demonstrations of MFCs have focused on practical device powering. ONR has demonstrated that MFCs can operate in environments that range from 10 to 1000m in depth, and from the tropics to the temperate Pacific Northwest coast.

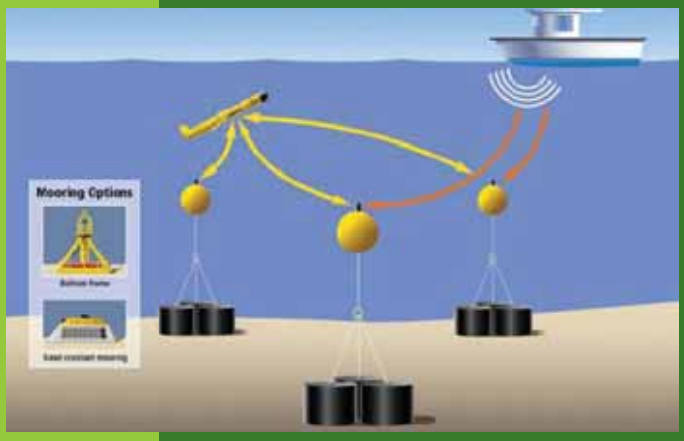
The Space and Naval Warfare Systems Center (SPAWAR)–Pacific may use MFCs to power hydrophones which track movement of endangered green sea turtles in San Diego Bay. SPAWAR-Pacific has also developed a diver-less deployment system which enables self-burial of the MFC-anode.



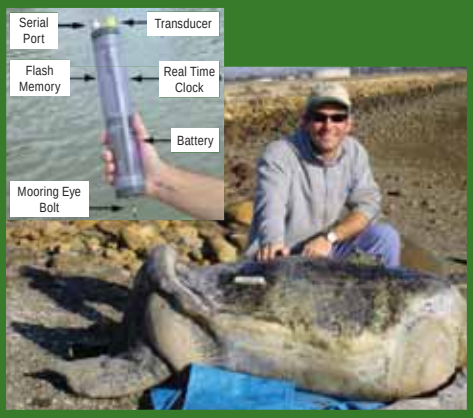

**Teledyne Benthos developed a highly efficient MFC power management package to enable powering of a compact acoustic modem.**




**Chambered MFC. Credit: www.kids.esdb.bg/images/Microbial_Fuel_Cell.gif.**



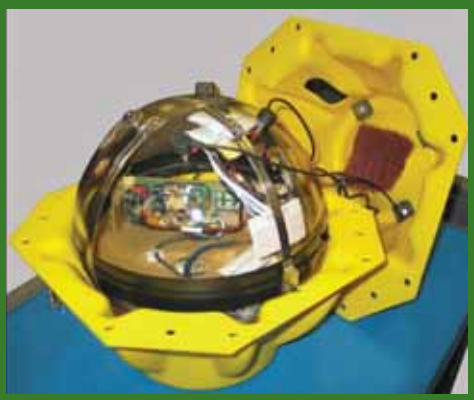

**A schematic showing a possible concept of operation.**




**(top) Receiver used to track signals sent from tags mounted on sea turtles (bottom), which has been adapted to use MFC power. Courtesy of Dr. Bart Chadwick, SPAWAR–Pacific.**

**Anodes (black cylinders above) used to generate power for a stationary acoustic array used for surveillance.**

**Teledyne power management package.**



**Teledyne Benthos SM-75 underwater modem used for the MFC MARS demo.**

The Naval Research Laboratory and SPAWAR–Pacific have been developing an MFC to continuously power a stationary acoustic array used for surveillance. This application requires numerous anodes (photo at left) to generate approximately 1W of power continuously.

Oregon State University, Teledyne Benthos and Harvard University have deployed an MFC system at 900m depth off the California coast at the Monterey Accelerated Research System (MARS) underwater observatory. This field study aims to determine if MFCs can power underwater modems along with other sensors (e.g., oxygen or water temperature sensors). Currently a Teledyne Benthos SM-75 modem (powered by the MARS observatory), receives data transmitted by compact, MFC-powered modems which are located several hundred meters away.

This ongoing demo, has proven that an MFC can successfully power an underwater acoustic modem as well as various sensors at impressive ocean depths (see http://www.mbari.org/mars/science/bmfc.html).


**MFC after being pushed into sediment with Remotely Operated Vehicle manipulator. Courtesy Oregon State University.**

## WHAT'S NEXT FOR ONR MFCS?

To date ONR's program has shown that MFCs are a viable option for powering many devices of interest to the Navy, such as acoustic pingers, modems, hydrophones and analytical sensors. As these proof-of-concept studies have been accomplished, the program is now focused on two main objectives: increasing power and improving reliability in diverse underwater environments. Within the next five to seven years we expect to deliver a safe, sustainable and reliable approach for meeting the Navy's needs for powering underwater surveillance systems. ■

# POWERING

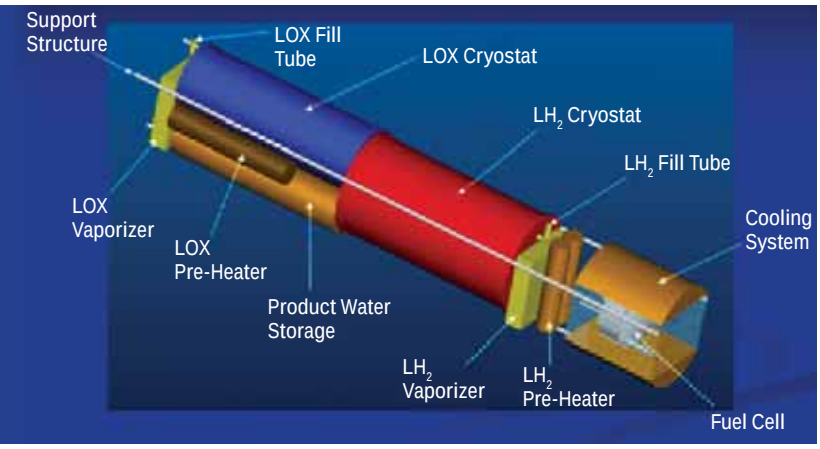
## THE LARGE DISPLACEMENT UNMANNED UNDERSEA VEHICLE FOR THE LONG HAUL

***Mr. Dan Deitz***, ONR Program Officer, Ocean Sensing and Systems Applications Division
***Mr. Eric Dow***, ONR Program Officer, Naval Materials Division

In today's world where most everyone is using small computers in their watches or phones, and supercomputers are a staple of almost any large industry, where you can even purchase a robot to clean your floors, it doesn't take much effort to look around and see that automation has removed the burden of some of our old tasks. Like the automated products you find in the commercial sector, the Navy and Marine Corps are also looking into these technologies as a way to reduce the manpower necessary to operate some of its most basic functions. In support of the Navy's mission to have world-wide presence and project power where and when it is needed, the Office of Naval Research (ONR) is taking on the task to fulfill this mission autonomously with the development of Unmanned Undersea Vehicles (UUVs).

In particular, the Large Displacement Unmanned Undersea Vehicle (LDUUV) Innovative Naval Prototype (INP) will develop the new technologies necessary to provide the Navy with the capability of operating UUVs for 60-90 days. This is a breakthrough for powering UUVs as the current state of the art is just over one week. The increased persistence of UUVs will allow for enhanced participation and awareness in many of the Navy's missions to include: antisubmarine warfare; intelligence, surveillance, and reconnaissance; and mine warfare. But the LDUUV INP can also have a large impact at home as well. The 90 day endurance period can provide constant weather sensors that improve our ability to forecast the weather and climate more accurately, can conduct more surveys of the critical shipping routes to ensure safe transit of commercial shipping, and can allow for more time at sea for scientific research in oceanography.

In a time of shrinking budgets, it is imperative that the Navy look to solutions that maintain its capability in an affordable way. The LDUUV




**UUV Fuel Cell Diagram**

INP provides the needed range and mission capability to complete core missions without the need for deployed Sailors or ships. When necessary, the LDUUV INP can go into the dangerous areas or sea conditions while keeping our Sailors and Marines safe on the ship or at their operating bases.

The LDUUV INP will push technology development in three major areas: the development of new high energy dense power systems that are safe aboard navy platforms; the ability to autonomously navigate in the littorals; and the creation of endurance technologies that allow a vehicle to operate in the open ocean for up to 90 days. The first technology development area is new UUV energy systems. Unlike many ships that can breathe air, the UUV must carry its own oxygen source. This means standard diesel engines will not work and more exotic sources must be considered. The UUV is also small compared to submarines with equivalent endurance. The LDUUV INP is looking for a very energy dense system of over 1000 Wh/kg. The scale of this research goal is like packing the LDUUV INP full of TNT and its energy output into your oven for 90 days, all while making it safe for use on ships. The challenge is in controlling the energy and efficiently drawing a small amount of it from a source as energy dense as TNT, while conducting operations safely in a naval environment.

The energy development is an enormous and somewhat daunting challenge when you consider these forward deployed and fully submerged UUVs need to operate continuously for greater than 60 days without re-charging. Just think about it, if UUVs were to rely solely on today's best batteries, they would operate for less than five days before needing to be re-charged! In addition to the primary challenge of storing large amounts of energy in small volumes, the secondary challenge is to develop power conversion technologies which are upwards of three times more efficient than today's best automobile engines all the while being much more reliable. Imagine being able to run you car's engine for over 1000 hours of continuous driving, or about 40,000 miles, without ever having an oil change or conducting routine maintenance! The technology solutions which are possible candidates to address these challenges are several, some of which could include stirling engines, solid oxide fuel cells, polymer electrolyte membrane fuel cells or thermal combustors, to name a few. Several of these technologies could be 'hybridized' or combined with other energy storage devices, such as batteries or capacitors, in an attempt to make the overall system more efficient throughout its operating regime as it goes from very low power (loitering, waiting) to very high power (accelerating, sprinting). Lastly, these systems must include any necessary energy storage sub-systems for efficient power conversion to the vehicles' payloads and propulsion system, all the while providing in excess of 600 Wh/l on a fully integrated systems basis.

ONR is on its way to solving these energy challenges and delivering to the Navy and Marine Corps innovative and safe UUV energy technology for the LDUUV INP. The LDUUV INP is anticipated to be testing this technology in 2018. These experiments will aim to demonstrate that UUVs can operate in the open ocean providing mission capabilities to both the Navy and the Department of Homeland Security, without the need for support ships. The energy technology emerging from the LDUUV INP program will provide the capabilities needed to meet the Navy's UUV near-term and far-term objectives in persistent, forward presence. Perhaps more importantly, it will enable manned platforms to be kept hundreds of miles removed from areas of conflict, resulting in reduced risk to naval personnel and platforms. ■

ONR'S TECHSOLUTIONS

# LIGHTS UP THE SHIP WITH GREEN TECHNOLOGY

***Ms. Dylan Ottman***, TechSolutions Program Analyst

United States Navy Sailors and Marines aboard submarines and surface ships know too well the irritating buzzing sound of fluorescent lights. Tired of the distracting sound made by fluorescents and the intensive maintenance procedures associated with the lighting fixtures, a Navy sonar technician decided to take action. Knowing there must be a better lighting option available, he reached out to the Navy's science and technology community hoping they could offer a solution. Luckily, he got in touch with the right team for the job: TechSolutions at the Office of Naval Research (ONR).

TechSolutions' projects are initiated in direct response to requests they receive from individual Sailors and Marines. The request to replace a noisy fluorescent bunk light with a quieter light bulb was submitted by a sonar technician at Submarine Force Atlantic (SUBLANT), Norfolk, VA. Not only are these fluorescent light fixtures noisy, but they contain hazardous materials, are maintenance intensive, and are easily damaged.

Upon receiving the request, TechSolutions began investigating alternative light fixtures. The three main light sources are incandescent, fluorescents and Light Emitting Diodes (LEDs). Incandescent light bulbs are an even older technology than fluorescent light bulbs. Incandescent light bulbs are highly wasteful and most varieties convert less than 10% of the energy they use into visible light, with the remaining energy used being converted into heat. LEDs are a newer technology and are gradually replacing incandescent and fluorescent fixtures. LED fixtures improve the ratio of visible light to heat generation and are considered energy-efficient lighting. In addition to the humming sound they make, there are other issues associated with these fluorescent fixtures that render them less than ideal for ships and submarines. Fluorescent fixtures are unreliable and require a lot of maintenance, they break easily, are noisy and expensive. LEDs also known as solid state lighting, are an excellent alternative to fluorescents, thus improving Sailors quality of life and helping to boost the Navy's energy efficiency.

Existing fluorescent lighting systems on board Navy vessels are maintenance intensive. The operational bulb life of the LED fixture is longer, lasting up to 50,000 hours, compared with the fluorescents, which only last up to 7,500 hours. The LED fixture's significantly longer life means it does not need to be purchased and replaced as often, thus minimizing maintenance for the Sailors and disposal costs for the Navy as well as reducing the number of spare bulbs needed. Unlike fluorescent bulbs, which contain mercury, LED bulbs contain no hazardous materials, thus further lowering disposal costs and eliminating special disposal procedures.

Another benefit of replacing the old fluorescent fixtures with solid state lighting is the improved energy efficiency across the fleet. Solid state lighting consists of low-power, high-reliability, light-emitting diode (LED) fixtures. The LED

**LED light designed by Energy Focus Ltd. (U.S. Navy photo by John F. Williams/Released)**

fixtures match the form, fit and function of the old 8WT5 fixtures and provide more light output for the same power input. Over time, solid state lighting could also help the Navy save in fuel costs and less fuel consumed could result in a cost savings for the Navy.

Naval leaders have issued a set of ambitious new goals to boost the Navy and Marine Corps' energy efficiency and solid state lighting supports their plans to make the Navy more green. One of these goals is to significantly reduce the Navy's consumption of petroleum. One of the main petroleum products used by the Navy is diesel fuel consumed by ships. Some of this diesel fuel is consumed by the generation of electricity used to power the lights on the ship. Because solid state lighting uses less electricity to generate the same light output, LEDs help to save fuel.

For this project, TechSolutions went above and beyond their typical scope of work in order to get the solid state lighting fixtures on board. While the LED fixtures matched the form, fit and function of the 8WT5 fixtures, TechSolutions first had to update the military specifications (MILSPECs) to allow the use of solid state lighting on board ships and submarines. Before TechSolutions could install the prototype technology on board any Navy vessel, they had to pay to have the MILSPECs changed to permit solid state lighting on board ships and submarines. Since the MILSPECs did not allow for the installation of solid state lighting fixtures on ships and submarines, the team funded not only the development and certification of the LED fixtures, but also had the Navy MILSPECs changed to allow solid state lighting on Navy ships and submarines.

TechSolutions' solid state lighting project improves the quality of life for Sailors. First, by replacing fluorescent bulbs with LED bulbs, Sailor's maintenance and repair workloads are significantly reduced. The LED fixtures do not break as easily and last longer than fluorescents, thus allowing Sailors to focus on more important challenges. Next, installing solid state lighting in place of fluorescents frees up storage space on the ship or submarine. A major issue for the Sailors on submarines is the lack of space for themselves and their equipment. Sailors currently have to store hundreds of additional fluorescent bulbs to replace broken bulbs. Also, Sailors must store broken bulbs on board, taking up even more valuable space.

"For over 22 years, I was an electronics technician on board a submarine where storage space is at a premium. Helping the Sailors free up some of the space used for storing light bulbs was in their best interest and therefore my priority," said Command Master Chief Ziervogel, head of the TechSolutions program under ONR's Director of Innovation.

TechSolutions solid state lighting could eventually replace fluorescent fixtures on board surface ships and submarines across the Navy. The Navy has already ordered more fixtures to be installed on board the USS New Hampshire. The original operational alteration to the USS New Hampshire has been extended from 33 initial fixtures to include all 8WT5 fixtures in the forward section of the ship. This includes 269 additional light fixtures for a total of 302 fixtures on board the USS New Hampshire. Solid state lighting is showing great promise on board Navy vessels and solid state lighting usage fleet-wide could add up to considerable savings and improved readiness. Solid state lighting is just one of several rapid response technologies being funded by TechSolutions using recommendations from Navy and Marine Corps personnel. ■

## About TechSolutions

**TechSolutions is a rapid-response science and technology (S&T) program focused on producing prototype technologies to meet requests submitted by United States Sailors and Marines. Rapid response technology reaches the fleet quickly and is significantly faster than the standard DoD technology acquisition cycle. TechSolutions is an innovative business process that works to bridge the gap between the warfighter and the scientist. Accepting requests directly from Sailors and Marines, TechSolutions teams up with government researchers to develop a solution. TechSolutions aims to put the prototype solution in the hands of the requesting warfighter within 12-18 months of their submission.**

THE BUSINESS OF ENGINEERING

# ALTERNATIVE FUELS FOR NAVAL SYSTEMS

***Ms. Sharon Beermann-Curtin***, ONR Program Officer, Power and Energy Technical Lead

When President Obama addressed the Nation at this year's State of the Union, it was clear that he has a strategy geared towards developing, "every available source of American energy," and that he is looking to the Navy to play a major role in implementing his clean energy plans:

*"And I'm proud to announce that the Department of Defense, the world's largest consumer of energy, will make one of the largest commitments to clean energy in history – with the Navy purchasing enough capacity to power a quarter of a million homes a year."*

From the statement made above, to the increased investment in energy programs, it is clear that the Navy is seen as a driving force in moving the nation towards the ability to use alternative fuels. In fact, Secretary of the Navy Ray Mabus has set ambitious alternative fuel goals for the Navy that are driving commercial research as well as market strategy. In particular, one of Secretary Mabus' goals is to sail the Great Green Fleet in 2016. The Great Green Fleet will likely include all of the platforms found in an Aircraft Carrier Strike Group and will demonstrate the ability to use alternative fuel sources in our current naval systems with no detrimental effects to the maritime or aviation systems. In the long run, the Navy is confident that our ability to use alternative fuels will ensure resiliency in the event of a global oil crisis.

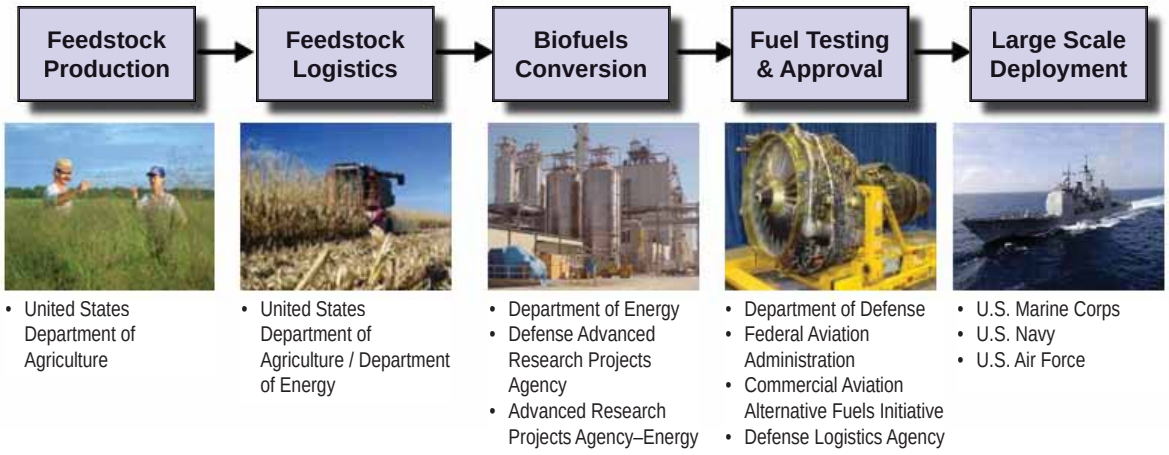
To achieve the Great Green Fleet goals the Navy needs to overcome a significant number of challenges. The Navy operates in harsh maritime environments and practices which introduce taxing parameters. The saltwater environment and our logistics for underway replenishment, as well as storage and handling, make it impossible to eliminate seawater from entering the fuel. The practice of seawater ballasting in fuel tanks is unique, adding additional opportunities for microbiologic induced corrosion as well as degradation of the fuel. In conjunction with the maritime environment challenge, the Navy also has to qualify a variety of fuels meant for different platforms (aviation fuels, e.g., JP-5, and maritime distillate fuels, e.g., F-76). The Navy has long life stability requirements as well as extensive handling from ship to ship as well as from shore to ship and from ship to aircraft. Lastly, there is a requirement for 'drop-in' fuels; all fuels qualified must work on existing systems.


The Office of Naval Research Alternative Fuels Program is investing in a variety of programs meant to enable the Navy and the Great Green Fleet in meeting their goals. Of note, ONR is currently producing predictive modeling tools that will allow faster and less expensive qualifications of new alternative fuels as they come into the market place. Conventional fossil fuels all must fall within a certain specification and fit for purpose properties. The Navy has expertise in working with fossil fuels; however, we need to bring in new techniques to establish the use of alternative fuels. Each alternative fuel that is being developed incorporates different conversion processes leading to a unique molecular make up. These chemical compositions determine a fuel's combustion characteristics. To qualify a fuel for each use on individual engines becomes cost prohibitive. Full engine testing requires 100,000 gallons of fuel to fully certify a new fuel. In addition, it takes time and expertise to run a full-scale test, all the while tying up valuable assets. The ability to predict the combustion performance given a molecular composition and integrating it with gas turbine and diesel engine

models, will allow the Navy to determine the ability of a fuel to perform on our systems before we invest in costly qualification testing. To-date, we have already witnessed the use of alternative fuels both commercially and in our naval systems; from the use of ethanol in our cars to the already demonstrated ability for aircraft to fly and ships to sail using alternative hydrocarbon fuels. However, the ability to bring a new technology to market goes beyond the technology itself.

The real driving force is the ability to bring the complete alternative fuels process into competition with fossil fuel costs. When looking at the challenge from this standpoint, it is necessary to point out that conversion technologies are 10-20% of the cost per gallon of biofuel. The bulk of the cost is in the feedstock production. One of the challenges is ensuring the amount of biomass as well as the reduction of feedstock cost, along with the ability to transport the feedstock to the refinery. The ability to persuade farmers to produce non-edible crops, effectively use fallow land, maximize growth management of feedstock and crop rotation, efficiently transport the feedstock to biorefineries through co-locating crops with relevant refineries, is no small feat and is a significant part of the process. The ONR Alternative Fuels Program is currently working with the USDA and the Department of Energy on these critical issues to ensure that when we need alternative fuels we will be in a position to not only use them but have a supply chain that is capable of providing sustainability. In the future the success of alternative fuels for the Navy systems and platforms will be determined by marketplace, infrastructure, and economics. ■

***Biofuels Supply Chain***

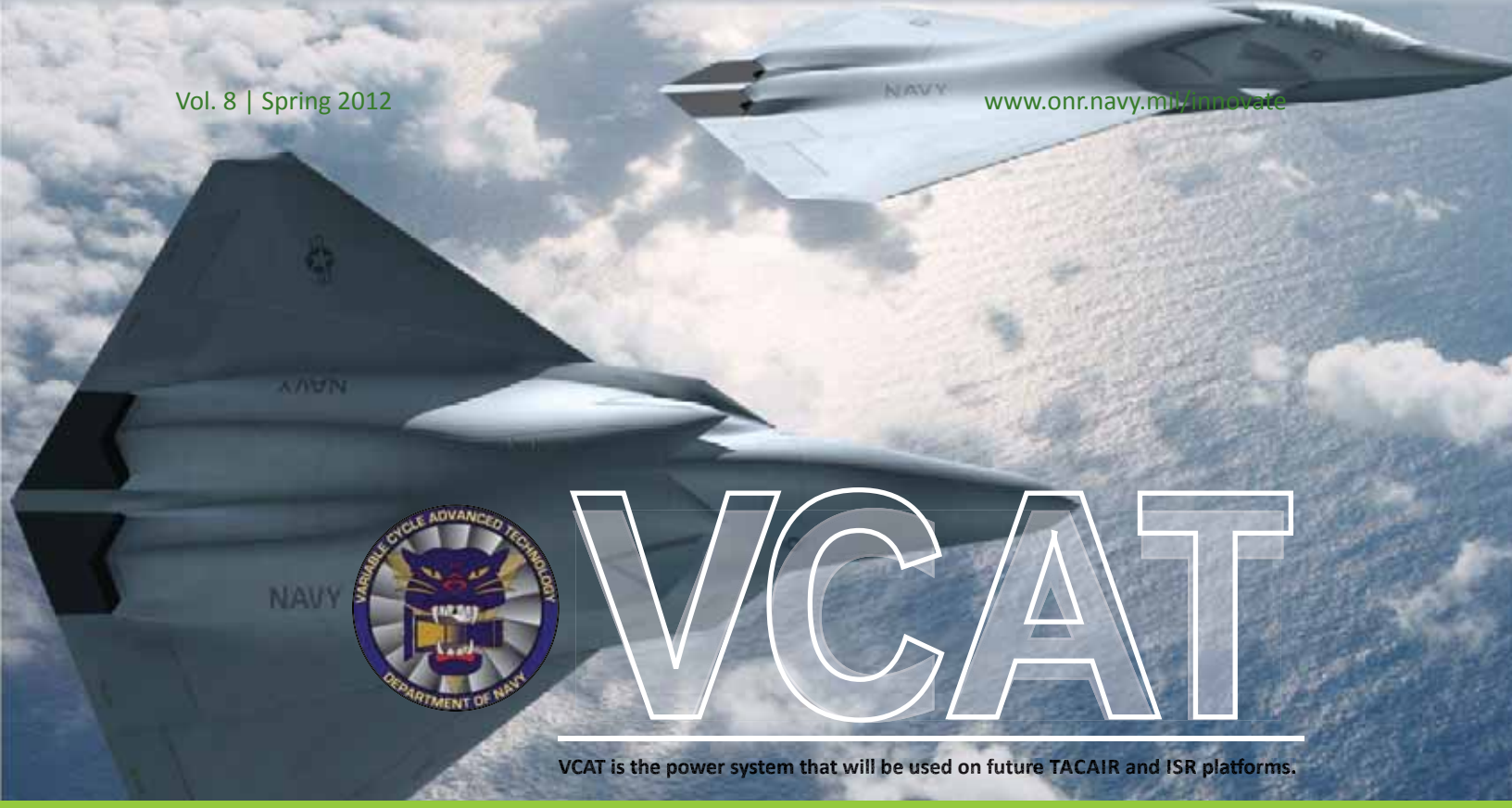



# VARIABLE CYCLE ADVANCED TECHNOLOGY
# FUTURE ENERGY SECURITY FOR NAVAL AVIATION

***Dr. Joseph Doychak***, ONR Program Officer, Division 351 Aerospace Science Research

The Office of Naval Research (ONR) is always thinking ahead and looking at what's around the corner. Rapidly rising energy costs and the volatility of energy supplies are two major challenges facing the Department of Defense (DoD) in the coming decades, and the Department of Navy (DoN) in particular. Naval aviation is destined to play a critical role in addressing these challenges. Recognizing that propulsion is a key technology enabling naval aviation's future capabilities to address these challenges, ONR is taking action by developing new engine technologies and making them available for future naval aviation missions.

Fuel costs and supplies remain volatile. DoD is the largest consumer of fuel amongst Government agencies. Aviation is the primary consumer within DoD. For the DoN, aviation ranks right up there with ships in terms of fuel usage. More efficient engines would enhance aircraft range and capability, and go a long way towards reducing the impacts of high fuel cost and supply volatility.




# VCAT

**VCAT is the power system that will be used on future TACAIR and ISR platforms.**

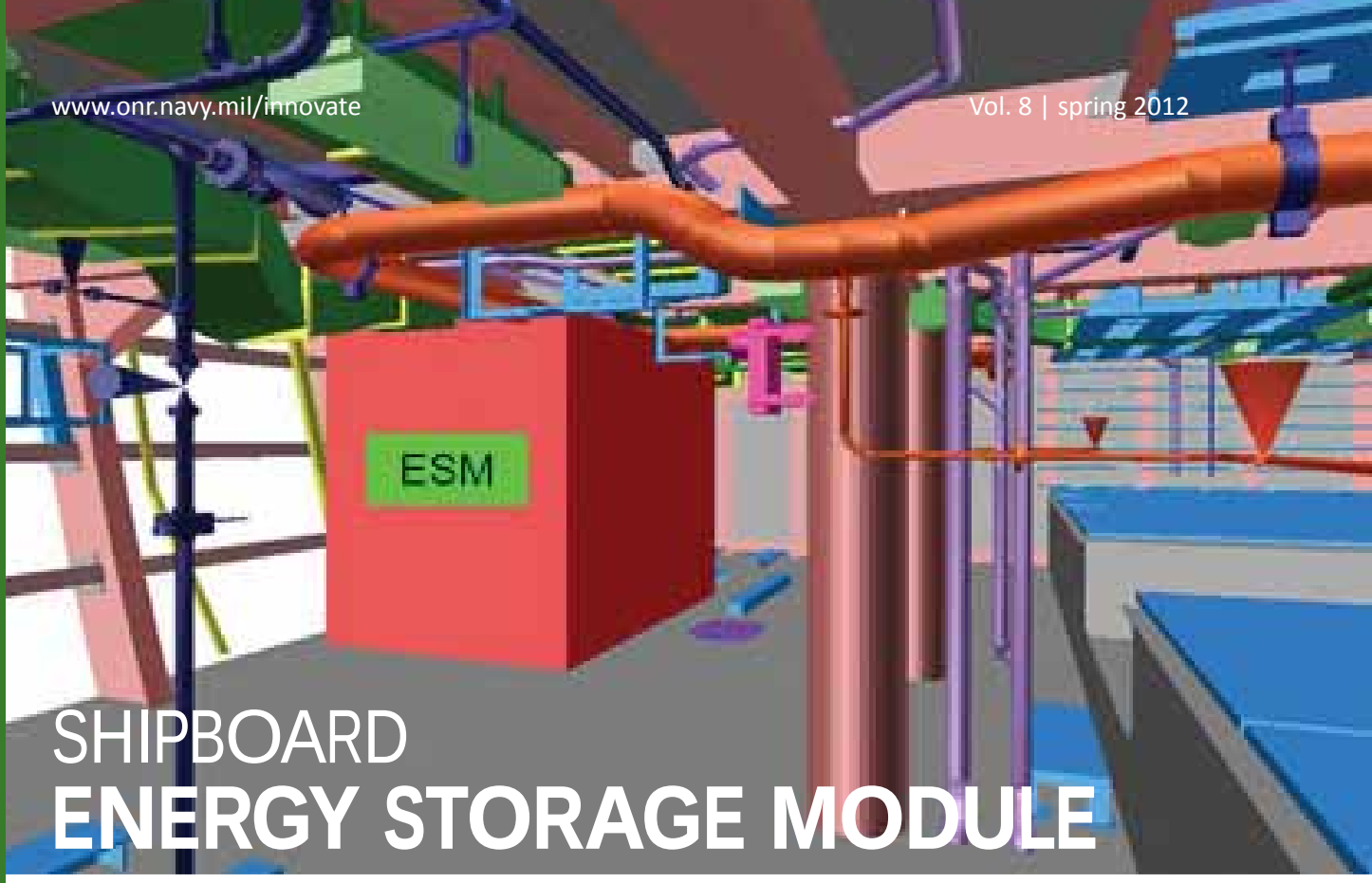
The most recent DoD strategic guidance titled "Sustaining U.S. Global Leadership: Priorities for 21st Century Defense," specifically calls out the need "to make the necessary investments to ensure that we maintain regional access and the ability to operate freely." More efficient propulsion systems will be required to extend the range and endurance of future Tactical Aircraft (TACAIR) and Intelligence, Surveillance and Reconnaissance (ISR) platforms.

Both the Air Force and Navy have been looking at variable/adaptive cycle turbine engine technologies. Variable/adaptive engine technology is any variable geometry engine component or feature that can be changed to optimize engine performance and adapt to multiple operating points within the aircraft's flight envelope. Similar to changing gears in a car, changing an aircraft engine's bypass ratio allows the engine to be optimized for high thrust when needed for takeoff, while maintaining the efficiency of a high bypass engine in cruise conditions. The ability to change these engine parameters inflight provides better performance and fuel efficiency across a range of flight conditions for naval aviation, yielding an increase in combat mission capability and reduced fuel needed to complete a given mission.

The VCAT program is a partnership effort between ONR and DoN's Task Force Energy (TFE) initiative. In close coordination with NAVAIR and the overall Naval Aviation Enterprise, the VCAT program's objective is to identify and mature critical variable/adaptive cycle turbine engine technologies for future carrier-based TACAIR/ISR naval aviation systems.

Details of technologies associated with those marinization and carrier suitability attributes were defined in a systems analysis effort initially funded by TFE at the beginning of fiscal year 2011. That study showed dramatic improvements in range and loiter capabilities for conceptual platforms and missions. The benefits were due to a combination of improved thermal and propulsive efficiencies from advanced material technologies and the variable/adaptive engine features. Aligned with TFE goals, the studies also showed that these technologies would offer the potential for significant reductions in fuel consumption—that means less demand for deployed fuel and tanker aircraft support.

Once specific requirements are established for the next naval TACAIR/ISR system, performance thresholds and objectives will be determined for the engine. Until that time, TFE goals associated with turbine engine efficiency and fuel burn reduction will be a primary driver for research on variable cycle technology. Enhanced capability for future naval aviation systems will continue to be an important part of the VCAT program's vision for the future. ■




# SHIPBOARD ENERGY STORAGE MODULE

***Mr. Donald Hoffman***, Program Officer,
ONR Ship Systems and Engineering Research Division 331

Presently, DDG-51 class ships account for a significant portion of the total surface ship fuel consumption. To reduce the fuel consumption levels in these ships, various methods are being used, including trail shaft operation as a common mode of operating the ship, and pitch scheduling. However, further fuel savings can be achieved through the incorporation of Single Generator Operations (SGO). SGO is an operating mode where only a single electrical generator is utilized to power an entire ship. This increases shipboard fuel efficiency through the reduction of the total number of Gas Turbine Generators (GTG) kept on line. Under the ONR SwampWorks, "Fuel Efficient and Power Dense Demonstrator" program, an advanced capability for SGO was examined and demonstrated.

The DDG-51 class engineering plant line-up includes four propulsion turbines (GE LM-2500) and three Gas Turbine Generators (Rolls Royce AG9140 GTGs). Standard electrical plant alignment has been to always operate a minimum of two GTGs. This significantly reduces the risk of losing all ship service power due to the failure of one GTG. While this practice maintains electrical plant integrity, the GTGs are operated routinely at low, specific fuel consumption design points which sacrifices efficiency and increasing time per engine. The specific fuel consumption for simple cycle gas turbines increases sharply, below 50% of load.

In order to keep electrical plant integrity during SGO plant alignment, a ride-through capability for essential services is necessary in case the GTG shuts down. This requires an instantaneous changeover of supply in power to ride through until standby GTGs can be brought back on line to assume ships load. Each GTG, by design, can be started and assume full load in 60 seconds after loss of shipboard electric power occurs. This requires an Energy Storage Module (ESM) which incorporates the energy storage device, such as batteries, and high density power electronics interface. The ESM needs to be of size to maintain critical ship's load at a minimum or transparent plant operations at maximum while allowing for multiple GTG start attempts. In addition, the ESM needs to be modular in design with high power density to allow for flexible backfit installations or future plant configuration.

Historically, conventional ESM designs have been extremely large and therefore not suitable for use in a shipboard application. Recent efforts undertaken by the ONR SwampWorks Program, have resulted in an increase of the power density and versatility of the ESM's power electronics. The overall ESM system design now allows more room for conventional battery storage, provides the generic capability to interface with multiple types of energy storage, and allows the ESM to be upgraded as new energy storage devices become available and proven for shipboard installation. What this really means is that insertion of these advanced energy storage technologies will provide longer operational duration and lighter weight with increased lifetime as compared to Navy state-of-the-art Valve Regulated Lead Acid (VRLA) batteries. VRLAs have typical lifetimes of five to seven years depending upon how they are cycled. Future insertion may include advanced large format lithium-ion batteries, once proper shipboard safety protocols have been addressed. Lithium-ion batteries are capable of far greater number of cycles with sustained performance and may offer lifetimes of double to three-times the life of a typical VRLA.

The ESM consists of a modular bi-directional AC/DC power conversion system, controls, thermal management system, and standardized system interface devices, to work with any type of energy storage device such as advanced lithium-ion battery system or conventional VRLA. Overall, the ESM interfaces with the ships 450VAC distribution and includes a high voltage DC-link for connection with the battery or other storage device. The development of multiple line replaceable units (LRUs) for the bi-directional AC/DC power conversion led to a 66% improvement in power density and 122% improvement in power capacity in comparison to a baseline LRU planned to be used in the DDG1000 Integrated Fight Through Power (IFTP) system. While the module size is notionally 600 kW (5 would support a 3 MW load), the system can be scaled to meet shipboard power and space needs. This modular concept is designed to be broken down into sub components to allow for shipment through existing ship hatches and passageways. The unit can then be reassembled in the required area for installation thus allowing for easy backfit on existing ships.

Overall, the expected benefits of utilizing the developed system include but are not limited to the following:

- Applicable to any shipboard class that uses gas turbine and diesel electrical power generation.
- Potential fuel savings: > 8000 bbl/ship/yr aboard DDG-51 Class ships.
- Potential to assist Hybrid Electric Drive – Propulsion Derived Ship Service operations for additional fuel savings.
- Reduction in potential for a "dark ship" condition.
- Flexibility for backfit installation utilizing existing shipboard hatch and passageways.

The ESM was successfully demonstrated by RCT Systems in December 2010. This technology has been transitioned to NAVSEA for further development. This development will include evaluation of operational aspects and support of GTG and shipboard systems integration.

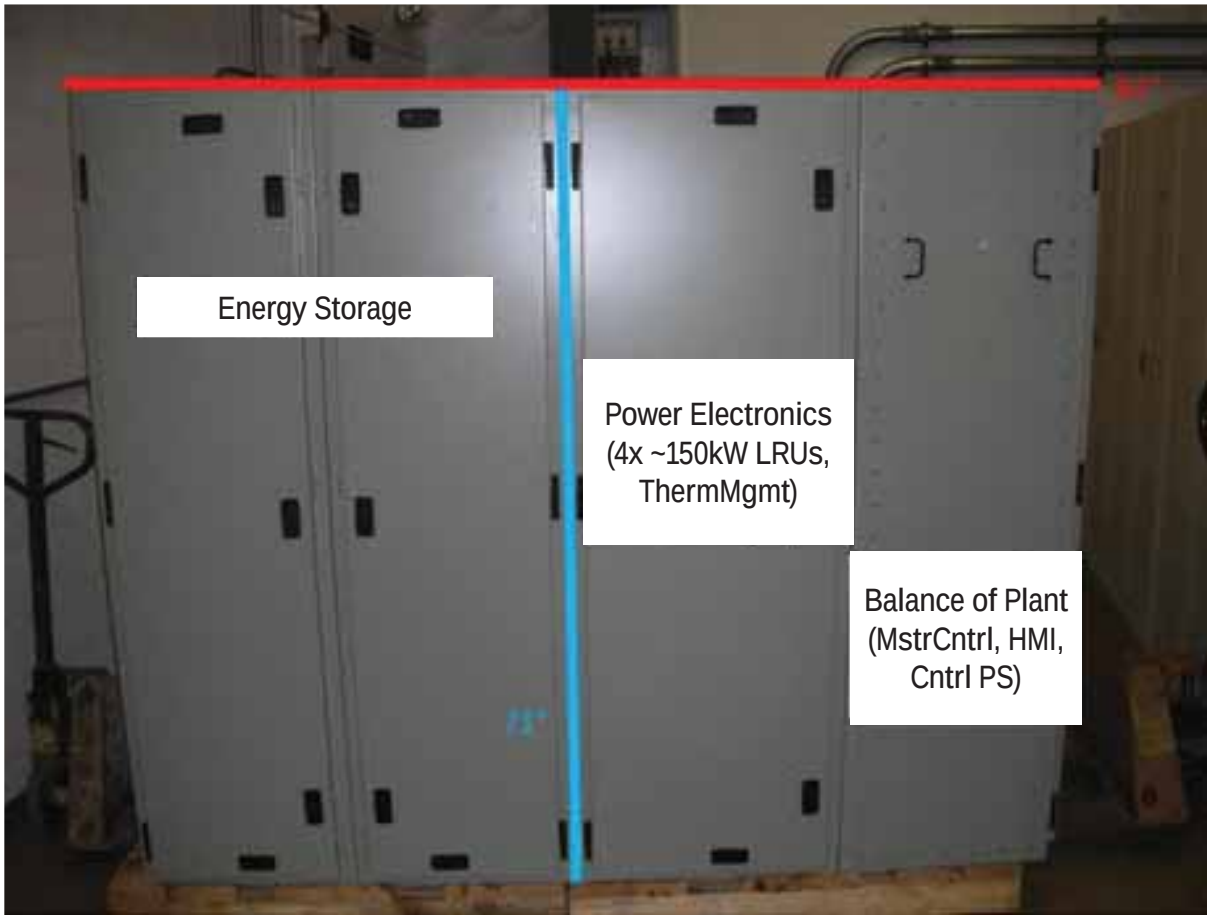
For the next generation of multifunction capability, ONR is presently examining Hybrid Energy Storage Module(s). Hybrid Energy Storage Module(s) with high power and energy densities, and high rate capability while achieving scalability at all power levels, will maximize performance, enhance fuel efficiency, and enable future high power weapons and sensor systems on legacy and next generation vehicles and platforms. This capability to store power dense electrical energy having variable charge and discharge rates in modular-reconfigurable packages is projected to extend fuel efficiency up to 40% in forward operating bases and military platforms, while providing robustness and easy maintenance. The development of hybrid systems with these energy and power capabilities poses a unique set of technical challenges. To surmount these shared and parallel challenges, a joint Advanced Research Projects Agency-Energy (ARPA-E) and Assistant Secretary of Defense for Research and Engineering (ASD(R&E)) program was announced by Secretary of the Navy Ray Mabus at the ARPA-E Energy Innovation Summit on 2 March 2011. ONR is leading the effort on the ASD(R&E) side

with an equal partner from ARPA-E. To date, this program has initiated efforts impacting tactical to improve fuel efficiency in the battlefield; aircraft to improve generator reliability; and large power for continuous pulse and fuel efficient operation. In collaboration, the ARPA-E's Advanced Management and Protection of Energy-storage Devices (AMPED) technology can then potentially extend the operational performance benefits and safety for these applications beyond the hybrid storage module baseline design configurations.

Overall, shipboard energy storage modules provide the potential to enhance operations and provide fuel savings aboard both legacy and future platforms. As ESM's component technologies improve in the future, their ability to be further integrated into shipboard electrical architectures and assist in maintaining overall system power quality will increase as well. ■

**ESM**

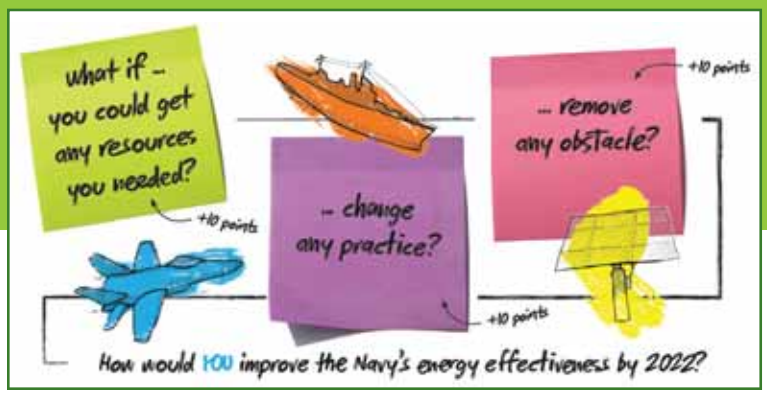
**ESM cabinet dimensions**



# Q&A WITH THE energymmowgli TEAM

CDR Jim Goudreau, OPNAV N45,
Task Force Energy

Dr. Larry Schuette,
ONR Director of Innovation




**1) In just a few sentences, please give the audience an explanation of what exactly Massively Multiplayer Online Wargame Leveraging the Internet (MMOWGLI) is:**

*(Dr. Schuette)* MMOWGLI is a new crowdsourcing tool that has been developed by the Office of Naval Research and its partners, Institute for the Future and Naval Postgraduate School, to solve tough problems facing the Navy and Marine Corps. MMOWGLI is an online game platform designed to elicit collective intelligence from an engaged pool of world-wide players to solve real problems. Multimedia techniques immerse players into the game, where compelling conditions engage their attention. Piracy off the coast of Africa was the successful debut scenario. This reconfigurable platform can be adapted to any scenario, and ONR will next use MMOWGLI to find creative solutions to power and energy problems. But it is a general-purpose tool suitable for many uses.

**2) What do you hope to achieve with energyMMOWGLI?**

*(CDR Goudreau)* We hope to increase the awareness of energy security as a national security issue as well as stimulating discussion that will allow the Navy to achieve greater energy resiliency and combat capability.

*(Dr. Schuette)* ONR is always looking for ways to bring new ideas into the building, to help build new concept of operations (CONOPs), and to be introduced to new principal investigators who can help us in our mission to develop future technologies for our Sailors and Marines.

**3) What made you decide energy for the game's scenario?**

*(Dr. Schuette)* With so many future outcomes in the energy arena and an expansive stakeholder community, we chose a topic that we thought would help unite such a ubiquitous field. Additionally, we wanted to find a customer outside of ONR to use the MMOWGLI platform and to benefit from the ideas played in the game. The Navy's Task Force Energy was a natural partner and they were interested in teaming up.

The MMOWGLI platform is suitable for tackling a broad range of challenges from macro-level issues that impact national security and multiple stakeholders to micro-level, programmatic challenges that impact a smaller community. After the pilot on Somalia Piracy, the MMOWGLI core team wanted to run a second scenario that would bring to the game a broad range of players from different organizations. Over the past decade, we have seen an increase in power and energy research and investment across DoD, government, academia and industry.

**4) Could you give us an example of what the first round of energyMMOWGLI would entail?**

*(CDR Goudreau)* The first round could be an examination of what our energy future looks like if we fail to act now. Every day that petroleum prices increase, it erodes our ability to train for

and execute operations that our nation demands of us. Little by little, that results in decreased combat capability, and that is something that we simply cannot accept.

**5) Do you anticipate more or less participation compared to the first MMOWGLI round?**

*(Dr. Schuette)* I think the first round of MMOWGLI gameplay benefitted from having the newness factor. However, I think this scenario is one that more people have a direct interest in. I think the Navy is going to get a lot of participation from the public and I look forward to reading some of the novel ideas that are exchanged in game.

**6) What types of players do you anticipate for this round of gameplay?**

*(CDR Goudreau)* We're hoping for an extremely diverse group of players including talented, thoughtful players from academia, industry, military, government, NGOs and global citizens.

**7) Other than the scenario, have there been any major alterations to the game?**

*(Dr. Schuette)* Since the pilot launched last year, we've made upgrades to the functions in the game such as in-game messaging which allows you to contact any player in the game without sharing your work or personal email addresses with anyone. We've also improved the game's supporting architecture to ensure that more concurrent players can join in on the action.

**8) What do you think is the biggest challenge for the Navy in regards to energy efficiency?**

*(CDR Goudreau)* Our challenge is two-fold, really. First, we have to make our existing Fleet more efficient since this is the Fleet we will have for the next 30-40 years. Even more importantly, though, we need to build into our culture the belief that energy efficiency is a key capability that delivers more combat capability and can help us prevail when we steam into harm's way.

**9) What do you think will be the biggest science and technology breakthrough in reducing energy use for the Navy?**

*(CDR Goudreau)* I don't think there will be any one single breakthrough that will solve all of our challenges. There's no silver bullet out there to make this go away. We'll achieve our goals through application of a range of technologies and approaches, while also changing our culture of consumption. How we behave is in some ways more important than what we are using, and we are looking to energyMMOWGLI to help us increase awareness of the need for change.

*(Dr. Schuette)* I think in order to answer this question you have to look at the problem holistically and through a business lens. The largest drivers of our Navy's energy costs are at the tactical edge: our ships and aircraft. We spend a significant amount of time and money getting fuel to these platforms. When looking across our Navy's assets and considering future technical investment, we have to consider the full life cycle of that platform with energy only being a piece of the challenge. When determining which technologies to invest in for the platform, we need to evaluate the trade space in terms of return in investment (ROI). Once you have an evaluation structure like this in place that considers ROI from the perspective of the Navy acquisition and sustainment communities, then you can decide what technology to invest in. Bottom line, we need to consider the value of the energy savings in order to make a smart investment in energy reductions.

**10) Do you think we will be able to reach the SECNAV's energy reduction targets by 2020? How?**

*(CDR Goudreau)* I think we will achieve them, but we have a long way to go and it will not be easy. Wise investments across a range of technology will be the key, along with culture change from the deckplates to senior leadership.

**11) When do you anticipate the game launching?**

*(CDR Goudreau)* We anticipate a great game taking place this spring, followed by more rounds of energyMMOWGLI in the future. ■

**SIGN-UP** for inside access to the game launch in Spring 2012
http://www.onr.navy.mil/energymmowgli

Charles Bridge, Prague, Czech Republic

## THE U.S.–CZECH INNOVATION CONFERENCE

# EXPLORING THE INNOVATION OPPORTUNITY

***Ms. Dylan Ottman***, TechSolutions Program Analyst

The Office of Naval Research (ONR) sponsored and facilitated an international innovation conference between the United States and the Czech Republic in Prague, March 5-6. The U.S.–Czech Innovation Conference: Exploring the Innovation Opportunity, brought together senior government policymakers, leaders in academia and pioneers in industry from both the U.S. and the Czech Republic in an effort to enhance U.S.-Czech cooperation in science and technology (S&T) innovation. The conference alerted Czech researchers to opportunities for funding from leading U.S. research organizations, allowed participants to reflect on past U.S.-Czech innovation conferences and current collaboration projects, enabled participants to discuss and appreciate major developments in innovation, and promoted discussion about noteworthy reports focused on innovation. Lastly, the conference deepened the innovation partnership between the U.S. and the Czech Republic based on the mutual understanding that in today's international marketplace innovation is the key driver of the future economy.

One of conference goals was to inform the Czech Republic of opportunities for funding from U.S. organizations to support Czech research. ONR funds Czech scientists who can rise to the level needed to solve some of the most critical international research challenges. The Czech Republic does not have a Navy, but they recognize the value in partnering with an organization that serves the U.S. naval forces and that could lead to technological and innovative advances in a many areas within their country. ONR funds S&T research that supports the warfighter; many of these programs have commercial applications as well and as a result, they have led to developments that improve the quality of life and increase security for civilians in countries around the globe.

"The U.S. Navy supports more basic research in other countries than any other U.S. service," Dr. Kassner, ONR's Director of Research, explained when asked how the U.S. and ONR could support the Czech Republic's innovation in S&T.

This is not the first time the U.S. and the Czech Republic have come together for an S&T-focused conference

and certainly it will not be the last. ONR has funded nine international scientific conferences in the Czech Republic since 2010; focus areas have included materials science, cyber security, human performance and military medicine, and signal processing. To date, ONR Global has funded five research grants in the Czech Republic for studies of multi-agent systems in air-space management, distributed control systems, trust management under uncertainty, distributed computing using graphics processing units, and cyber security.

The U.S. and the Czech Republic conference participants agreed that in today's highly competitive interconnected world every country's number one priority is to use S&T to create innovation and translate S&T into business opportunities. A high quality of life for every country's citizens is dependent upon quality jobs, which primarily come from or as a result of opportunities and developments in S&T. During the conference, both nations' representatives referenced a report popularly referred to as the "Gathering Storm," to emphasize the importance of S&T in every country. In "Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future," the National Academies conducted a review of America's competitive position in a newly evolved global landscape and concluded that, "not only is the world flat, but in fact it may be tipping against us." Released in 2005, the report emphasized that innovation will be the primary driver of the future economy and that concurrent growth of jobs in the 21st century will be a direct result of progress in science and engineering.

Meetings such as the U.S.–Czech Innovation Conference allow both countries to ask bold, critical questions and call attention to research that attempts to answer these questions. In this newly evolved global marketplace, both the U.S. and the Czech Republic recognize the vital importance of investing in innovation partnerships today. It is difficult to see where today's basic research will lead us in the future with much certainty. However, both countries see that investments made in S&T along with efforts to leverage world class international research will spark new innovation and produce stronger economies. ■

## NUMBERS

**30%**

Navy energy use is 30% of total DoD energy use.

**75% & 25%**

The Navy uses 75% of its energy afloat and 25% ashore.

# DIRECTOR'S CORNER

## LENGTHENING THE LEASH

***Dr. Larry Schuette***,
ONR Director of Innovation

Conflict over natural resources is as old a theme as warfare itself. If you peel back the onion of past conflicts what has been rationalized on simpler terms can also be explained by what resources could be found in the contested region. While the interest in maintaining access to oil from the Arabian Gulf is well known, there are other examples that while more subtle are still visible today. For example, Barbara Tuchman in her (excellent, highly recommended) book "The Guns of August" articulates well the dynamics of World War I and its antecedents. One of those was the Franco-Prussian War of 1870. The young German Empire insisted on annexing Alsace-Lorraine both for the strategic border shift it would provide but also for the iron ore found in the region. The reverberations from that conflict have echoed for more than a century.

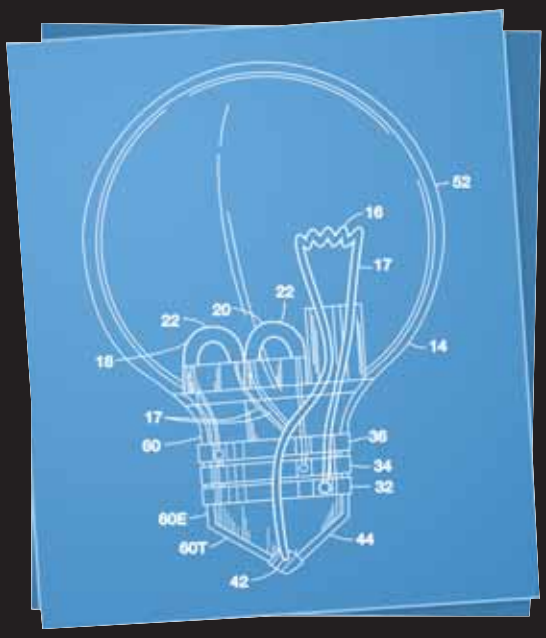
In the last century, the U.S. Navy switched from coal to oil as the principal means of energy for its ships. (N.B., we can thank President Theodore Roosevelt for the shift to oil; I can't imagine doing an Underway Replenishment with coal.). Easily transported, available worldwide, oil is the fuel of choice for trucks, planes and ships: and as a strategic resource is fought over. The Department of Defense has worked hard to secure and protect the fuel used by our defense systems and platforms. Thus oil is a double edged sword: the very thing responsible for enabling operations and therefore providing national security has put our Sailors and Marines lives and security at risk while protecting its transport.

Our national policy to reduce energy consumption and switch to alternative fuels provides strategic and tactical advantages to the Department of Defense. The strategic advantage occurs because an increase in energy efficiency implies a global reduction in competition for resources. At the tactical level there are implications on land and at sea. On land, fewer fuel convoys are required to resupply the troops and marines in the field. Fewer convoys mean less risk to the troops providing convoy protection. At sea, an increase


in energy efficiency means less need to replenish fuel which translates to fewer tankers and the tactical advantage of a longer leash.

With new research into innovative power and energy systems and alternative fuels comes a realized desire to make changes that can lead towards, "lengthening our leash." Power and energy (P&E) is one of those topics that impacts a wide variety of technical areas. At the Office of Naval Research (ONR) we have programs across all departments looking to advance our capabilities in P&E. ONR invests in programs in compact power conversion technologies that are geared towards enabling the Navy's Next Generation Integrated Power Systems aboard future surface ships and submarines. We are sponsoring research into silicon carbide switches that enable compact, lighter, and energy dense power conversion. We are sponsoring energy efficient jet engines for next generation aircraft. We are working with other government agencies such as the U.S. Department of Agriculture to develop sustainable biomass production. In short, we are powering forward as a research community to help our Navy meet its energy goals.

You see, we need to lengthen our leash just a little and that can make a significant difference. It's a starting point and one that ONR and the naval research community takes seriously. ■




# INNOVATION
## BEYOND IMAGINATION™

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