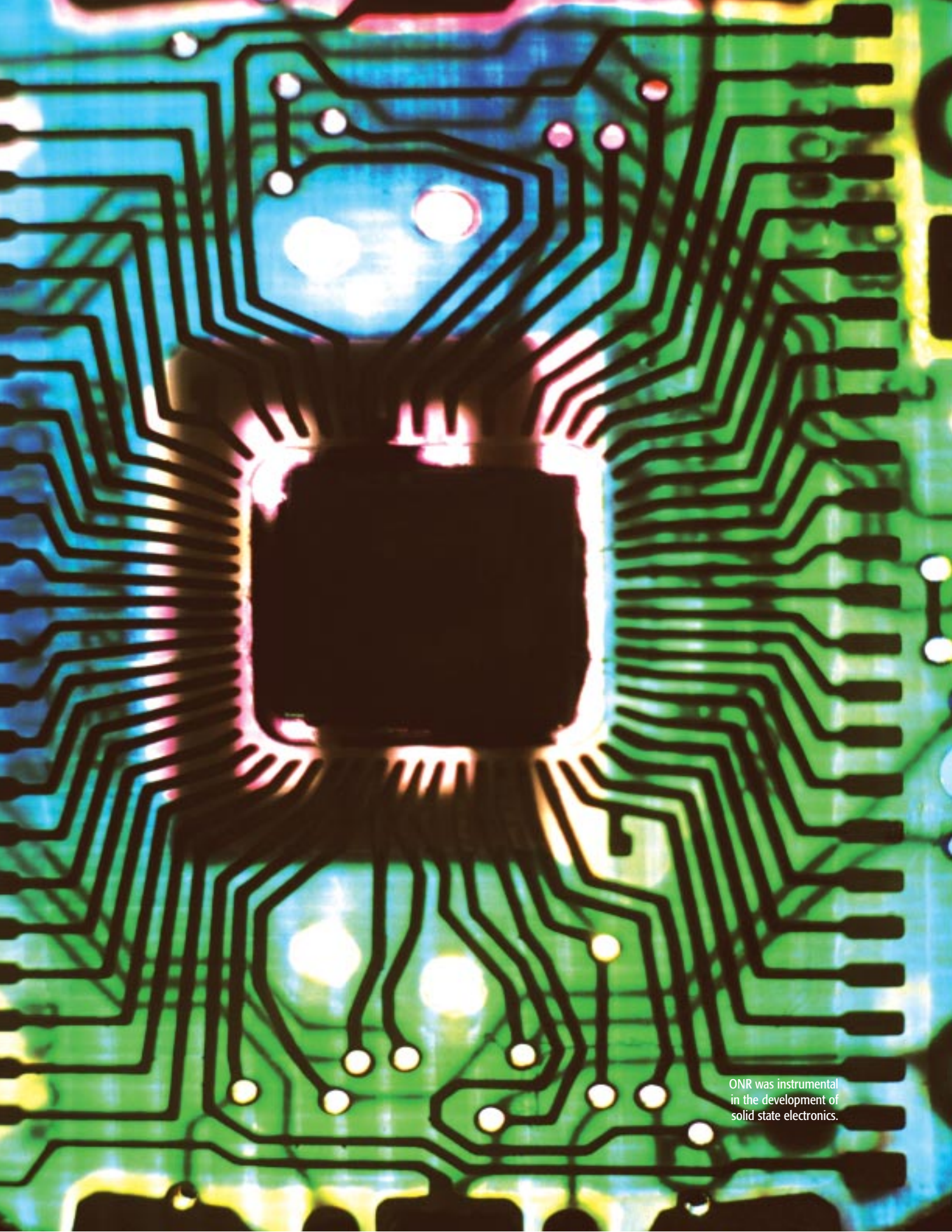
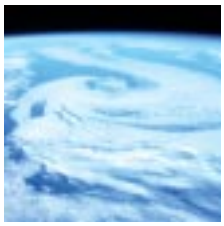


ONR was instrumental in the development of solid state electronics.

Rear Admiral Nevin Carr & Dr. Richard Carlin Discuss Past, Present & Future Investments in Energy



On 19 September 2011, Rear Admiral Nevin Carr, Chief of Naval Research at the Office of Naval Research (ONR), and Dr. Richard Carlin, Head of ONR's Sea Warfare and Weapons Department spoke with Kenneth Hess from the public affairs staff at the Chief of Naval Operations Energy and Environmental Readiness Division (N45) about ONR's past, present and future investments in energy.

CURRENTS: Good afternoon Admiral Carr. Could you please give us a brief summary of your background and experience?

REAR ADMIRAL NEVIN CARR: I'm a surface warfare officer. I've been in the Navy for about 34 years—most of which has been spent at sea—deployed on cruisers and destroyers. So like Admiral Cullom, that's the lens through which I view energy conservation—from first-hand experience. That means being able to extend the legs of our ships at sea and our aircraft in the air, and to get more tactical use as well as more independence from foreign supply.

NRL is the interface between science and technology and Navy and Marine Corps warfighting needs.

Rear Admiral Nevin Carr.

CURRENTS: Give us an overview of the mission and vision of ONR.

ADMIRAL CARR: ONR traces its roots back to the Navy Research Laboratory (NRL) that was created around 1916. ONR was created in 1946. NRL began as a mechanism for the Navy to get visibility into and pull technology solutions from the world of science and technology (S&T) with a Navy-relevant perspective. It's been tremendously beneficial over the years. NRL has produced life-changing technologies like the Global Positioning System (GPS). The early days of research into nuclear propulsion also began there, before it was handed off to the Naval Sea Systems Command (NAVSEA), where it resides so well today. NRL is the Navy's corporate laboratory and the interface between S&T and Navy and Marine Corps warfighting needs.

This office was created in 1946 in the aftermath of World War II to maintain the momentum and the connectivity that was created during the war

REAR ADMIRAL CARR led the Office of Naval Research from December 2008 through November 2011, and plans to retire from the Navy in January 2012.

Rear Admiral Matthew Klunder took over as Chief of Naval Research on 17 November 2011.

effort when the world of S&T really came together to support the country.

ONR actually pre-dated the creation of the National Science Foundation (NSF). So for a number of years, the Navy's research effort effectively functioned as the nation's national science foundation. Later on, when NSF came into being, we handed off a lot of what we used to do to them although we still work that interface with NSF.

CURRENTS: What have been your priorities for ONR?

ADMIRAL CARR: My priorities have always been to make sure that we're investing in the very best science that gives us the most return on our investment—and to make sure that we're talking closely with the Navy and Marine Corps. We want to make sure that whatever we're doing meets their needs. And there probably is no better example of that than in power and energy.

ONR has nine focus areas that drive our research. One is dedicated completely to power and energy. Our focus there is on increasing energy security and providing more efficient power and energy systems.

Secretary Mabus has been a leader, along with Admiral Roughead and Admiral Cullom, in opening the Navy's exploration of alternate sources of energy as well as different ways of using and conserving energy. And that fits very nicely into our mission which is to look for areas in the world of S&T where we can support those requirements.

CURRENTS: Could you give us an example of how you're helping to achieve those goals?

ADMIRAL CARR: A lot of our focus most recently has been on alternative fuels. As the Navy moves to adopt alternative fuels, whether they're biofuels or other sources, we need to ensure that whatever chemical

The Basics About the Office of Naval Research

ONR PROVIDES THE science and technology necessary to maintain Navy and Marine Corps technological advantage. Through its affiliates, ONR is operational in 50 states and 70 countries as well as 1,035 institutions of higher learning and 914 industry partners.

President Truman established ONR in 1946 to "plan, foster and encourage scientific research in recognition of its paramount importance as related to the maintenance of future naval power, and the preservation of national security."

Some of ONR's accomplishments include SEALAB I and II–the world's first underwater living habitats–which were launched in the mid-1960s. SEALAB enabled researchers to live underwater for as many as 30 days. In 1981, ONR created the Navy Operational Global Atmospheric Pressure System, the Navy's first global numerical weather prediction system–used today by the Department of Defense and civilian forecasters throughout the world. More recently, ONR has developed such diverse technologies as:

1. Naval applications for autonomous unmanned undersea vehicles and unmanned aerial vehicles
2. Sand abatement technology to counter improvised explosive devices
3. QuickClot™–an agent used to reduce soldier mortality from blood loss

In 2008, ONR conducted a record-setting fire of an electromagnetic railgun. The technology uses high power electromagnetic energy instead of explosive chemical propellants to accelerate a projectile along a pair of metal rails. The resulting launch propelled the projectile further and faster than any gun in history.

When it comes to patented discoveries and inventions, according to a 2010 report published by the Institute of Electrical and Electronics Engineers, the U.S. Navy holds the number 1 ranking among all international government agencies–underscoring the fact that Navy research laboratories and partnerships are focused on producing innovations and intellectual property that Sailors and Marines depend on.

energy source that we include is compatible with our existing infrastructure. A large part of our focus has been on ensuring that compatibility—testing the fuels to make sure that they can co-exist with existing fuels and infrastructure. Our job is to make sure that the fuels the Navy is looking at are viable, compatible, and will be there.

The Navy is heavily involved in stimulating and guiding the market, but ultimately we expect to follow the market.

DR. RICHARD CARLIN: I think it's very important to keep in mind that a lot of the work we do is to directly support the Secretary's energy goals. There has been a strong emphasis on biofuels, but as Admiral Carr pointed out, regardless of where everything goes, we're prepared. Biofuels are important because they are sustainable.

We've teamed with the U.S. Department of Agriculture to conduct some biofuels research in support of the Secretary's memorandum of understanding.

ADMIRAL CARR: The generation of energy that we use begins with fuels. But it doesn't end there. We also look across the spectrum of energy to include how we convert the chemical energy in fuel into mechanical, thermal or other forms of energy that we use. That might mean more efficient turbines that burn at hotter temperatures or innovative ways to extract more energy. It means looking at ways we manage energy once it's generated. We're very interested in an all-electric architecture for a ship. If you can do that—if you can convert energy one time from the chemical energy in the fuel to your end-use form of energy—that's very efficient. For example, if we can convert the chemical energy in fuels to kinetic energy out of the barrel for a projectile that we launch electromagnetically, there are a number of steps that we can eliminate. Take legacy gun systems for example. We have to manufacture chemical propellants for projectiles then package, transport, store, protect, load, and use them. So if you could get to an electrical environment where you convert energy one time into electricity and directly to kinetic energy for a projectile, the magazine could conceivably be the safest place on the ship—because all of the energetics are moved out of the magazine and into the fuel tanks.


Dr. Richard Carlin.

There are lots of other advantages in an electric ship environment. We are working very closely with NAVSEA and Program Executive Office-Ships to explore the best ways to do this—to manage the energy electrically aboard the ship for use in sensors, weapons, propulsion, and hotel services (e.g., sleeping quarters, food, water, personnel hygiene, etc.). In fact, Dr. Carlin talked about this at a recent electric ships research and development consortium.

DR. CARLIN: As Admiral Carr pointed out, an important piece of this is the need to move forward from fuels generation and distribution to the use of those weapon systems. We don't expect to be changing our infrastructure. And the Navy is heavily involved in stimulating and guiding the market, but ultimately we expect to follow the market. The generation, the distribution, the power densities that are required, the speed at which these things have to operate, endurance—these are very challenging for Navy systems to operate properly. We've had to take the lead in terms of developing a lot of these technologies and taking advantage of the work already being done in the market.

The electric ships research and development consortium was established a number of years ago to provide a pipeline of future power electronics engineers for the Navy. That was back in the days when power electronic engineering was really quite suppressed throughout the country, when everybody went to circuit board development. So the consortium was established to address the unique aspects of electric

A Brief History of the Global Positioning System

THE SEEDS FOR what became the GPS were planted in 1957 when the Soviet Union launched the Sputnik satellite. Scientists immediately recognized that this "artificial star" could be used as a navigational tool.

In the 1960s, NRL and the Aerospace Corporation independently developed concepts for systems that could provide precise, all-weather, real-time, worldwide navigation information 24 hours a day. In 1973, NRL's program merged with the Air Force program to form the Navstar GPS program.

The first satellite in the Navstar GPS was launched in 1977. In more than 700 air, land, and sea tests conducted between 1977 and 1979, the satellites exceeded all performance requirements and affirmed the system's extraordinary precision.

The satellites transmit a constant signal generated by on-board atomic clocks, which are so precise that they gain or lose only one second every three million years. Users equipped with a receiver/processor simply lock onto the signals of four satellites, and latitude, longitude, altitude, and velocity are automatically computed "within meters" by triangulation.

On 10 February 1993, the National Aeronautic Association selected the GPS team as winners of the 1992 Robert J. Collier Trophy, the most prestigious aviation award in the United States. This team consisted of researchers from NRL, the U.S. Air Force, the Aerospace Corporation, Rockwell International Corporations, and IBM Federal Systems Company. The award recognized Roger L. Easton, an NRL scientist, as the principal inventor and designer of the GPS.

Though invented for defense purposes, such as targeting pinpoint strikes and positioning troops, the 24-satellite GPS system now serves many peacetime functions such as air traffic control, scientific surveying, harbor navigation, measurement of ocean waves, and of course, assisting drivers in locating their destinations.

Sources:

National Park Service, www.nps.gov/gis/gps/history.html
Navy Research Laboratory, www.nrl.navy.mil

ships—the architecture, the movement into directed energy, to advanced radar and the unique electronics that you have to have. In the process of doing that, we worked with the Defense Advanced Research Projects Agency (DARPA) to develop silicon carbide systems—solid state electronics. Some of the solid state electronics you see out there now were funded by ONR. In fact, we visited the ABB Group a while back and they thanked us for our contribution to their large plant, in terms of the solid state electronics that they've developed. *(Note: The ABB Group is comprised of several power and automation technology companies that enable utility and industry customers to improve their*

Silicon carbide has huge potential to change the amount of electricity we have to use on the far end.

performance while lowering environmental impact. They operate around the world in more than 100 countries. Visit www.abb.com for more information.)

ADMIRAL CARR: When you talk about power and energy, you're talking about fuels and sources from which we get energy—the processes by which we convert that into energy—engines, turbines, and so on. In the middle is how you manage that energy. So we look across that entire spectrum. Dr. Carlin just mentioned silicon carbide, which has huge potential to change the amount of electricity we have to use on the far end.

ONR's Nine Focus Areas

THE NAVAL SCIENCE and Technology Strategic Plan describes how ONR will enable the future operational concepts of the Navy and the Marine Corps. The plan outlines nine S&T focus areas derived from naval capability needs. The vision for each of the focus areas are:

1. **Assure Access to the Maritime Battlespace**
   Assure access to the global ocean and littoral reaches and hold strategic and tactical targets at risk. Sense and predict environmental properties in the global ocean and littorals to support tactical and strategic planning and operations. Improve operational performance by adapting systems to the current and evolving environment.

2. **Autonomy and Unmanned Systems**
   Achieve an integrated hybrid force of manned and unmanned systems with the ability to sense, comprehend, predict, communicate, plan, make decisions and take appropriate actions to achieve its goals. The employment of these systems will reduce risk for Sailors and Marines and increase capability.

3. **Expeditionary and Irregular Warfare**
   Naval warfighters of the future will possess the full spectrum of expeditionary kinetic and non-kinetic capabilities required to defeat traditional threats decisively and confront irregular challenges effectively.

4. **Information Dominance**
   Enable the warfighter to take immediate, appropriate action at any time against any desired enemy, target or network by assuring that autonomous, continuous analyses of intelligence, persistent surveillance and open information sources have, at all times, optimized the possible courses of action based on commander's intent.

5. **Platform Design and Survivability**
   Develop agile, fuel efficient and flexible platforms capable of operating in required environments. Enable manned and unmanned naval platforms and forces to operate in hostile environments while avoiding, defeating and surviving attacks.

6. **Power and Energy**
   Increase naval forces' freedom of action through energy security and efficient power systems. Increase combat capability through high energy and pulsed power systems. Provide the desired power where and when needed at the manned and unmanned platform, system and personal levels.

7. **Power Projection and Integrated Defense**
   Enhance extended-range power projection capabilities and integrated layered defense by improving manned and unmanned naval platforms, enabling forces to complete missions in hostile environments by avoiding, defeating and surviving attacks. Demonstrate improvements in standoff indirect precision fires on time-critical targets, while limiting collateral effects through the use of electromagnetic kinetic projectiles, hypersonic missile propulsion, scalable weapons effects, directed energy and hypervelocity weapons.

8. **Total Ownership Cost**
   Support the goal to reduce Total Ownership Cost (TOC) by developing and aiding the insertion of technology to reduce platform acquisition cost, reduce lifecycle and sustainment costs and achieve crew manning requirements. TOC includes all costs associated with the research, development, procurement, operation, and disposal of platforms, combat systems and associated elements over the full lifecycle.

9. **Warfighter Performance**
   More effective point of injury care for Sailors and Marines. Enhanced health and warfighter performance both afloat and ashore. Highly efficient and effective human-system performance aided by new technologies created through the exploitation of biological design principles. Enhanced warfighter and system performance with reduced personnel costs as a result of the right information being provided to the right people with the right skills at the right time in the right jobs.

To read the entire plan, visit www.onr.navy.mil.

There are other ways we're looking at reducing loads so that ships and aircraft can use less energy—slippery paints for ship bottoms, for example, that NAVSEA is now using. Electric weapons are a different way of using energy on the far end. If you look at all the energy that had to come together to put one five-inch projectile in the barrel with a propellant charge behind it, think of what you would have saved by converting energy one time. Now, like the compatibility of fuels, any future systems like this—whether they're future electronics that are silicon carbide-based, or future guns like the ones I'm describing—aren't going to happen overnight. There will be a long period of transition. And so as we look across the spectrum of energy usage, we are very mindful of where we can realize the most gain in the near term. We're very mindful of return on investment. There are some very interesting long-term solutions out there—highly technical, very complex but very tempting. At the end of the day, fuel is really just an arrangement of carbon, hydrogen, and oxygen atoms. You can rearrange those atoms pretty much any way you want. It just takes energy to do that. So there may come a day when we can manufacture fuel from other sources. But that's a long way off.

Sometimes we make the most of our investments by being a fast follower.

But it's something we see some potential for. There are methods today—Fisher Tropsch is one of them—to do this. They require more energy into them than you get out of them. You never gain energy. But if you can use energy from an abundant source to do this, you might be able to gain advantage in the overall energy management and usage equation.

Now we're not just focused on ships. We're also collaborating with DARPA, the Air Force, and the Office of the Chief of Naval Operations on an aircraft engine. We're focused on supporting shore energy usage, which is a huge component of the energy that we use and one of the main thrusts of Secretary Mabus' energy goals. It's also one of Dr. Carlin's favorite subjects.

CURRENTS: Any specific technologies to share in that arena?

DR. CARLIN: We help to drive the technology forward and that's a very important goal of ONR. We're early adopters as well. We push and pull. Take fuel cells as an example. We've spent lots of money on research and now we're starting to take that in. In our unmanned systems, we have programs that are looking at some early pre-commercial technologies and how they might be applied for Navy systems such as General Motors vehicle fuel cell technology for manned undersea vehicles and small, light fuel cell units from Protonex for unmanned air vehicles. A very important aspect of this is the actual return on investment—pertaining especially to shore facilities where many technology options are available and many new ones are being developed. There are a lot of incredible technologies to choose from. How do you make those decisions? You need to make sure when you make those choices, the investments that you're making have a long-term payoff in terms of energy savings. We have big challenges associated with the use of energy systems in the Pacific region—humidity, the tropical environment, rain, and so on—pose unique challenges. So how well these new technologies actually function in those environments and what return we will get on our investments, has yet

Admiral Carr speaks with Steven Marlin (left) and Richard Rosado, from General Motors, about an ONR fuel cell vehicle during New York Fleet Week in 2011.

to be proven over a 30 to 40 year time span. We are making some of those evaluations from the different alternative energy resource areas.

ADMIRAL CARR: While we ensure that we are investing Navy and Marine Corps technology dollars in the smartest possible way, we won't necessarily be on the leading edge of every new discovery. Sometimes we make the most of our investments by being a fast follower. In the power and energy environment, there are a lot of technologies that are being driven by the commercial market from which we can benefit. The Navy has been a leader in some areas—biofuels and a willingness to push the edge of our own known technologies and requirements to name a couple. But there are other areas including fuel cell research where the automotive industry has been taking the lead.

Once we unlock the promise of unmanned vehicles, they're going to operate for very long periods of time without human intervention.

They're not quite there yet but they've invested millions of dollars and millions of hours of research into developing fuel cells. That has provided us with a head start into adapting fuel cells developed by the automotive industry for unmanned underwater vehicles. Because fuel cells are efficient at generating low levels of electricity over a long period of time, they may prove to be a very powerful application for the long duration, unmanned underwater vehicle missions.

We expect to get up to 90 days from hydrogen fuel cell applications. In fact, we have a fuel cell up and running over at NRL that we're working on in collaboration with General Motors. Unmanned vehicles are a very interesting application for power and energy. Once we unlock the promise of unmanned vehicles, they're going to operate for very long periods of time without human intervention. They are going to need to have a power source and be very efficient in the use of that electricity. We're attacking that problem from both ends of the spectrum.

The silicon carbide types of electronics that Dr. Carlin mentioned—more efficient sensors, more efficient batteries to store the energy—all these things are being driven by the uniquely challenging aspect of unmanned vehicle development. However, they will all provide benefits that can be scaled up to larger applications like ships, aircraft, tanks, and shore energy. So we don't have to invent everything. Sometimes it's smart to leverage somebody else's invention.

Dr. Peter Matic, head of the multifunctional materials branch at NRL, explains his work to Admiral Carr at the Navy League Sea Air Space 2010 Exposition.

CURRENTS: You've touched on crossover with industry.

ADMIRAL CARR: In something like power that's ubiquitous, there is a lot of crossover. Sometimes there's duplication of research. Not all duplication is bad—as long as we understand that duplication. A rich competition of ideas is your best hedge against some of those ideas not panning out.

CURRENTS: Talk about some missions that ONR and N45 are collaborating on—or areas that might be ripe for collaboration.

ADMIRAL CARR: We are very closely coupled with N45. They're a resource sponsor and we're a technology organi-

zation. Admiral Cullom and I are Naval Academy classmates. We grew up in the surface Navy together and we communicate quite a bit about this and other issues. As I mentioned, we have nine focus areas that drive our research. One pillar is dedicated exclusively to power and energy. Admiral Cullom is a co-chair for that team. Rich (Dr. Carlin) does a lot of our point work with N45.

DR. CARLIN: We're very supportive of what N45 has been doing over the years and directly support them with technology. As members of Task Force Energy, we provide the technology piece. Other groups represent various components of the acquisition community. N45 has responsibility for developing the energy portfolio for the Navy. They have done a tremendous job of pulling those pieces together and establishing a structure that brings all of those resources together while we provide the S&T piece.

We have an extensive outreach effort to inspire and fund young students with naval-relevant content.

We see biofuels as one of the strongest links across Navy components. Program folks from the Naval Air Systems Command and other system commands are making sure that we continue to make progress toward the goals that Secretary Mabus has set for the Green Fleet.

The Future Naval Capabilities (FNC) piece mimics what is being done in some of those same working groups—working on the broad spectrum of issues for which N45 is responsible as a resource sponsor. Those same working groups are working with the FNC group which is making investments in S&T. If we know what those longer term needs are, the resource sponsors and the acquisition process—through the Task Force Energy process laid out by N45—can help guide those S&T investments. It's truly a team effort.

ADMIRAL CARR: And N45 and ONR joined hands in 2009 to sponsor the first Naval Energy Forum. *(Note: The third annual Naval Energy Forum was held 13–14 October 2011. For more insights into the results of the forum, see our article entitled, "Highlights of a Charged Energy Awareness Month" on pages 26–28 in this issue of* Currents*.)*

CURRENTS: Could you give us the bottom line on how and why power and energy are important to the Navy?

ADMIRAL CARR: It's all about the whole energy spectrum. It's about generation and it's also about storage, management, and usage. We try to work our way across that spectrum.

Admiral Carr discusses undersea science and technology with students from Wilson High School after an awards ceremony honoring retired Capt. Don Walsh, first commander of the Navy bathyscaph Trieste.

Finally, as the country and the Navy and Marine Corps face our energy challenges, it's critical that we continue to draw from our pool of highly technically skilled young scientists and engineers. A lot of our workforce is aging. We will need to replace much of our workforce in the coming years—and the supply of students in this country for science and technology, engineering and math is not keeping up with the demand. So we have an extensive outreach effort to inspire and fund young students with Naval-relevant content. We want to encourage them to embrace technical subjects and consider a career supporting the Navy in uniform or as an engineer or scientist.

U.S. Navy photos by John Williams.