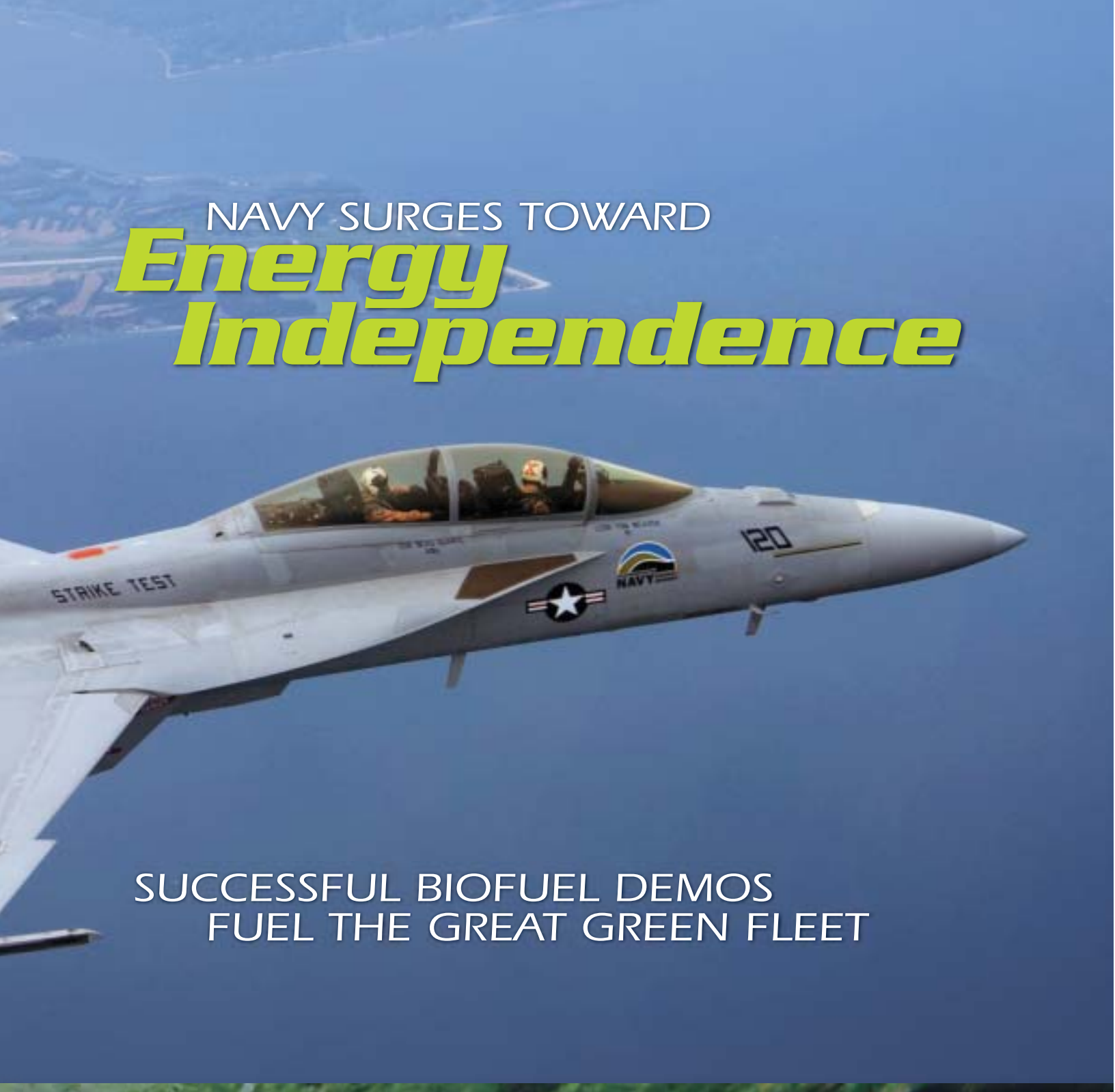
An F/A-18F Super Hornet strike fighter, dubbed the "Green Hornet," conducts a supersonic test flight at Naval Air Station Patuxent River. The aircraft is fueled with a 50/50 Camelina seed-based biofuel blend. This Earth Day 2010 test drew hundreds of onlookers, including Secretary of the Navy Ray Mabus, who has made research, development, and increased use of alternative fuels a priority for the Navy.

NAVY SURGES TOWARD Energy Independence



SUCCESSFUL BIOFUEL DEMOS FUEL THE GREAT GREEN FLEET

A series of successful demonstrations of camelina- and algae-based biofuels in several types of aircraft and small boats in 2010 and 2011 is propelling the Navy toward the Great Green Fleet.

In 2009, Secretary of the Navy Ray Mabus announced his plan to fuel half the Navy's energy consumption through alternative fuels by 2020. "We're doing this for one reason," Mabus stated, "We're doing it to be better warfighters."

THE BASICS ABOUT THE

Navy Fuels Team

The Navy Fuels Team is part of the Naval Fuels and Lubricants Cross Function Team. The team is comprised of technical experts from across the Navy. Officially chartered in 1999, the team includes representation from the aviation, ship, logistics, research and operational communities. The team's mission is to provide a single source of fuels-related technical expertise, guidance and solutions to all levels of the Navy.

We buy too much fuel from potentially or actually volatile places on earth.

—Secretary Ray Mabus

Mabus explained how energy security and national security go hand-in-hand. "We buy too much fuel from potentially or actually volatile places on earth. We give them a say on whether our ships sail, whether our aircraft fly, whether those ground vehicles operate because we get our fuel from them."

Another major contributing factor is cost. When Mabus first announced the Navy's energy goals in 2009, the price of a barrel of oil was $76. Just two years later, the price averages around $100. For every $1 increase in the price of a barrel of oil, the U.S. military faces $31 million in additional fuel costs.

Even more importantly, Mabus reported that for every 50 convoys, one Marine is either killed or wounded.

Developing the First Aviation Biofuel

When the Secretary announced his alternative energy goals, the Navy Fuels Team was already working on a biofuel specification. Based at the Naval Air Station (NAS) Patuxent River, Maryland, the team had begun testing small amounts of biofuels in 2008. Their work accelerated when the Secretary's goals were announced.

"The Navy Fuels Team has the job of taking the fuels that various manufacturers and refiners are producing and getting them approved," states Rick Kamin, Navy Fuels Team Lead.

"We wrote a procurement specification that specified the performance properties for the bio component of the aviation fuel blend," Kamin continued. The new fuel blend had to meet the following operational requirements:

- It must be a drop-in replacement for the petroleum-based fuel.
- It must meet or exceed the performance requirements of the petroleum-based fuel. (There must be no notable operational differences.)
- The biofuel must be able to be successfully mixed or alternated with petroleum fuel.
- The biofuel must require no modifications or enhancements to the configuration of the aircraft or ship.
- The biofuel must require no modifications or enhancements to the Navy's existing fuel storage or transfer infrastructure.

Navy Biofuels Timeline

CAMELINA
ALGAE

F/A-18 Green Hornet — APR 10

Rigid Hull Inflatable Boat — JUL 10

Riverine Command Boat—Experimental — OCT 10

MH-60S Seahawk — NOV 10

2010

Navy Fuels Team Lead Rick Kamin and his team wrote the specification for the new biofuel and supervised testing which led to its approval.

An MH-60S Seahawk helicopter tests a 50/50 Camelina seed-based biofuel blend at NAS Patuxent River. The test demonstrates another step toward the certification of fuels from non-petroleum sources for use in all Navy and Marine Corps aircraft.
Sean Seremet

"Although, we were looking for a sustainable plant—and/or algae-derived oil—that was not competitive with food crops, we did not specify that it needed to be a camelina-based fuel," explained Kamin.

The team sent the procurement specification for JP-5 jet fuel to the Defense Logistics Agency (DLA) Energy (formally known as the Defense Energy Support Center), which has the responsibility of purchasing fuel for the Department of Defense (DoD). An open solicitation was put forth to the energy industry to develop and produce a suitable fuel, and in 2009, a contract for almost 600,000 gallons of biofuel (190,000 gallons for the Navy and 400,000 gallons for the Air Force) was awarded to Sustainable Oils, Inc.

Sustainable Oils supplied test fuel created from the oil of a mustard seed known as camelina. The team then began an aggressive schedule of laboratory testing, followed by component and engine testing. The camelina-based JP-5 was blended with petroleum-based JP-5 in a 1:1 blend then tested in the laboratory and test stand without a hitch.

In early 2010, an F/A-18 Green Hornet fighter jet became the first aircraft to fly on the biofuel blend. It was this same Green Hornet that took to the skies at NAS Patuxent River for a series of 16 test flights—including a high-profile flight on Earth Day 2010, which marked the first time that an aircraft had flown faster than the speed of sound on biofuel-blend jet fuel.

Mike Rudy, the Green Hornet program's Environment, Safety and Occupational Health Coordinator, was pleased with the results of the demonstrations. "We observed no operational difference with the biofuel," he confirmed. Subsequent tests confirmed that the JP-5 fuel performed to specifications.

Following the success of the F/A-18 test flights, numerous other platforms were tested with the 50/50 blend fuel. In November 2010, a MH-60S Seahawk helicopter—the next generation submarine hunter and multi-mission helicopter—took to the skies above NAS Patuxent River. Test results indicate that the aircraft performed as expected, through its full flight envelope with no degradation of capability.

The MH-60S is designed for anti-surface warfare, combat support, humanitarian disaster relief and search and rescue, aero medical evacuation, special warfare and organic airborne mine countermeasures.

THE BASICS ABOUT *Biofuels*

Neither the camelina- nor algae-based biofuel being tested by the Navy Fuels Team is derived from a feedstock that competes with food crops—an important factor in the Navy's biofuel selection.

Camelina (*Camelina sativa*) is related to mustard and rape seeds. Its seed can be 40 percent oil and has a similar chemical structure as petroleum. Other benefits of camelina are that it is a valuable rotation crop for wheat and is grown when a field would otherwise lie fallow. Its water and fertilizer input requirements are minimal. (For more on information on converting camelina into a biofuel feedstock for the Navy, read our cover story in the winter 2011 issue of *Currents*.)

The type of algae-based fuel being tested by the Navy is a hydro-processed renewable diesel, better suited than other biodiesels to equipment operating in the marine environment. Various permutations of algae-based fuels are being created and tested worldwide in automobiles, ships and aircraft.

We observed no operational differences with the biofuel.

—Mike Rudy

In 2011, test flights were fast and furious at NAS Patuxent River and elsewhere. In June, the Seahawk flew again, this time with an algae-based biofuel blend. (See our sidebar, "The Basics About Biofuels.") This flight marked the first time an algae-based fuel was used in any military aircraft. It validated in operation what was confirmed in the laboratory, that different renewable hydroprocessed feed sources producing similar oils could be used interchangeably. This ability to use multiple renewable sources to produce a similar fuel would vastly increase potential supply sources without having the need for each to undergo costly test stand evaluations.

In August 2011, the MV-22 Osprey became the first Marine Corps aircraft and the first tilt rotor vehicle to be flown on a biofuel blend. The Osprey hovered just above the runway for about a minute, then took off for the skies, eventually reaching an altitude of 25,000 feet. The MV-22 is a tilt rotor, multi-mission aircraft that combines the functionality of a helicopter with the long range and high speed of a turboprop aircraft.

Later that same month, a T-45C Goshawk training craft successfully flew with the camelina fuel blend. The T-45C Goshawk is a tandem-seat aircraft used by the Navy and Marine Corps to train pilots on carrier and

An MV-22 Osprey lifts off from NAS Patuxent River during a successful biofuel test flight. The tilt-rotor aircraft flew at altitudes of up to 25,000 feet on a 50/50 blend of camelina-based biofuel and standard petroleum based JP-5 fuel.

Steven Kays

A T-45C Goshawk training aircraft conducts a test flight using a biofuel blend of JP-5 jet fuel and plant-based camelina.
Kelly Schindler

The Blue Angels flew F/A-18 fighter jets powered with camelina-based biofuel on Labor Day weekend 2011.

tactical mission operations. The test flight was performed by the "Salty Dogs" of Air Test and Evaluation Squadron (VX) 23.

On Labor Day weekend, the biofuel blend faced its ultimate performance test at NAS Patuxent River as the Blue Angels performed at the base's air show. In the most public demonstration of biofuel use to date, six F/A-18 jets soared, dipped, and flew in trademark formations—all without a hitch.

Also in September, an EA-6B Prowler became the first aircraft in the electronic warfare category to fly under biofuel power. The Prowler is a long-range craft, capable of jamming and intercepting enemy radar, data and commu-

FOR MORE
Information

For more insights into the road that led to this series of test flights with biofuels, see our article entitled "From Seed to Supersonic: How Camelina Powered the Navy's Premier Fighter Jet" in the winter 2011 issue of *Currents*.

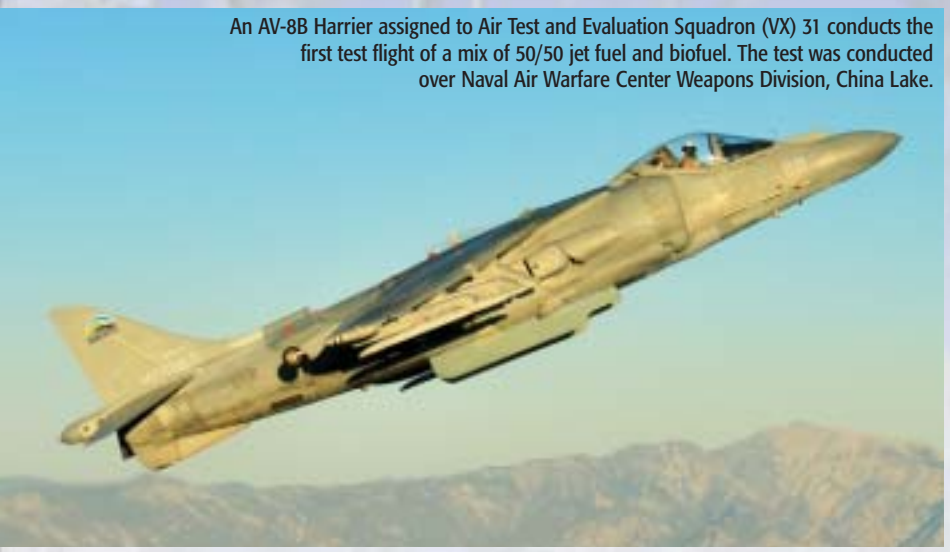
There were no observed differences in the ship's performance, even at full power.

nication signals. Captain John Green, program manager for the EA-6B, emphasized that, "given the EA-6B Prowler's critical role in joint warfare it was important that we complete this qualification to allow Carrier Air Wings and expeditionary sites the operational flexibility to utilize biofuel."

Meanwhile, on the west coast, personnel from the Naval Air Warfare Center Weapons Division, in China Lake, California performed a biofuel flight test on an AV-8B Harrier. According to Hal Bennett, project lead for the AV-8B biofuel flight test program, the testing was flawless. The short-takeoff vertical landing aircraft rolled down the runway several hundred feet, took off, then accelerated into a maximum performance climb. Testing included phasing maneuvers, hard cranks, wind up turns, hard turns with nozzle biting and even some inverted flight.

The seventh and final test aircraft took to the skies in September. An MQ-8B Fire Scout successfully flew the first unmanned biofueled flight at Webster Field in St. Inigoes,

An EA-6B Prowler flies over Southern Maryland on a biofuel blend of JP-5 aviation fuel and camelina oil.
The Prowler successfully completed its inaugural biofuel flight here continuing the Navy's surge toward energy independence.
Kelly Schindler



An AV-8B Harrier assigned to Air Test and Evaluation Squadron (VX) 31 conducts the first test flight of a mix of 50/50 jet fuel and biofuel. The test was conducted over Naval Air Warfare Center Weapons Division, China Lake.

An MQ-8B Fire Scout UAV successfully completed the first unmanned biofuel flight at Webster Field. The aircraft flew with a combination of JP-5 aviation fuel and plant-based non-food source camellia. Fire Scout is the seventh and final aircraft to demonstrate the versatility of biofuel through its use in all facets of naval aviation.

Kelly Schindler

Maryland. Powered by the camelina blend, the craft was piloted by the Unmanned Aircraft Systems Test Directorate. Rear Admiral Bill Shannon, Program Executive Officer for Unmanned Aviation and Strike Weapons, stated, "I am very pleased we can add MQ-8B to the list of successful bioflights completed at NAS Patuxent River this year, bringing us one step closer to achieving the Navy's energy goals."

The Fire Scout is a Vertical Take-Off and Landing vehicle designed to provide troops with situational awareness, intelligence and surveillance.

Making Waves on the High Seas

While the Navy Fuels Team was developing and testing their JP-5 blend, they were simultaneously working on an algae-based fuel for use in ship engines. In January, 2011, the team conducted testing on marine gas turbines using a 50/50 mixture of F-76 petroleum and algae-based biofuel.

This fuel received its first "road test" in July 2010, when a Rigid-Hull Inflatable Boat (RHIB) set sail at Fort Monroe, Virginia. The RHIB, a high-performance 7-meter craft, was tested alongside an identical vessel powered by 100 percent petroleum. There were no observed differences in the ship's performance, even at full power.

In October 2010, in the waters off Naval Station Norfolk, Virginia the Navy reached another milestone on the road toward energy security. Conducting a full power demonstration of an alternative fuel-powered riverine boat, the

Locomotive Joins Fleet

OF ENVIRONMENTALLY FRIENDLY AIRCRAFT & BOATS

An environmentally friendly locomotive made news when it entered service at the Naval Support Activity (NSA) Crane, Indiana. Used for transporting ordnance, the new "N-ViroMotive" is a 120-ton switcher locomotive that runs on biodiesel fuel, consumes half the fuel of conventional models, and is certified by the U.S. Environmental Protection Agency for low emissions. (For more information about NSA Crane's green locomotive, read our article entitled "Fuel-Saving Green Locomotive Debuts at NSA Crane: Base Accepts Delivery of First Environmentally Friendly Locomotive" in the spring 2011 issue of *Currents*.)

Which Biofuel Is Best?

It's difficult to say. **Camelina**, though it has many advantages, is currently not being planted in sufficient quantities to fuel the Great Green Fleet. **Algae** offers a much higher yield, and may be a more promising option, but there are currently several competing methods for growing microalgae. One intriguing project, involving algae production in the ocean, is profiled in the spring 2011 issue of *Currents*. Read our article entitled "NASA & the Navy Developing the Fuel of the Future: Joint Effort Investigating Algae Farms in the Ocean."

The Navy has commissioned the largest ever purchase of biofuel by the U.S. government.

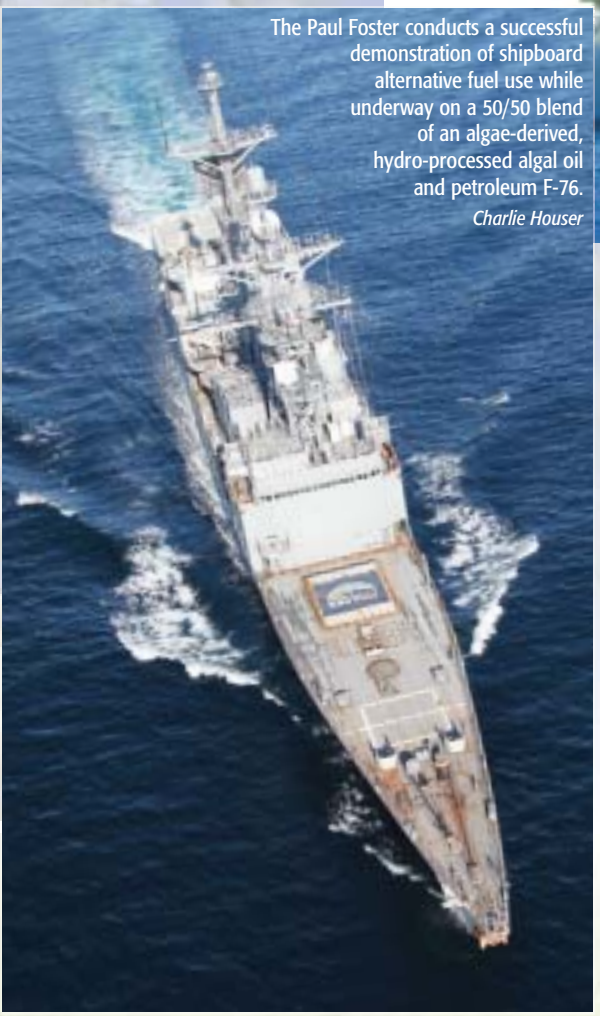
Riverine Command Boat—Experimental (RCB-X) ran on a 50/50 blend of algae biofuel and petroleum, achieving a top speed of 44.5 knots (about 52 miles per hour).

"Running the RCB-X at its maximum power throughout this test of a second generation marine biofuel was a Wright Brothers moment for the Navy," stated then-Rear Admiral Philip Cullom, director of the Energy and Environmental Readiness Division on the Chief of Naval Operations staff, which leads the Navy's Task Force Energy. It was the first time a naval surface vessel from any nation has ever been driven at full power on biofuel, let alone one derived from algae. (Note: As of 7 March 2012, Cullom was promoted to Vice Admiral and took over as Deputy Chief of Naval Operations for Fleet Readiness and Logistics (N4).)

In October 2011, a Yard Patrol (YP) boat became the next platform to successfully operate on the algae-F-76 blend. The YP boat is a

Sailors assigned to Riverine Group 1 conduct maneuvers aboard Riverine Command Boat (Experimental) (RCB-X) at Naval Station Norfolk. The RCB-X is powered by an alternative fuel blend of 50 percent algae-based and 50 percent NATO F-76 fuels.

MC2 Gregory N. Juday



The Paul Foster conducts a successful demonstration of shipboard alternative fuel use while underway on a 50/50 blend of an algae-derived, hydro-processed algal oil and petroleum F-76.
Charlie Houser

Landing Craft Air Cushion (LCAC) 91 is underway on a 50/50 mix of alternative fuel and F-76 diesel.
Jonathan Gibson

108-foot training boat used at Naval Academy, Annapolis, Maryland. Once the Waterfront Readiness Department tests biofuels in YPs and confirms that they operate as well as conventional fuel, they will likely turn their attention to refueling more of the YPs with biofuels according to Senior Chief Engineman Ted Hayhurst.

That same month, a conventional Landing Craft Utility (LCU) 1600-class, went through its paces with the new fuel. Designed in the 1970s, the LCU can transport up to 400 combat-equipped troops or 18 tons of equipment over relatively short distances, from a ship or seagoing base to shore. During its maiden voyage using the biofuel blend, the LCU operated at full load, over a wide range of engine speeds with no discernable problems.

On 16 November 2011, the Navy launched its largest test of algae as a fuel component off the California coast. The USS Paul F. Foster, a retired destroyer turned self-defense test ship, sailed from San Diego to Port Hueneme, California. 20,000 gallons of the algal-blend fuel powered the ship's one propulsion gas turbine and one ship service gas turbine. Experts onboard monitored the ship's temperature gauges and propulsion, its performance at different speeds, and how much fuel it expended during the 17-hour trip. Though performance data are yet to be evaluated, all indications point to the success of the voyage.

In parallel, a joint project was underway between Maersk Line Limited and the U.S. Navy to test biofuels for their long-term suitability for maritime applications. By the fall of 2011, the Navy Fuels Team was monitoring emissions on biofuel-powered engines, and testing to determine the potential effects of biofuels on the engine's fuel system performance and normal wear and tear.

The final biofuel demonstration of 2011 occurred in Panama City, Florida in December when the Navy tested an algal-petroleum fuel on a Landing Craft-Air Cushioned (LCAC) hovercraft. The hovercraft achieved a top speed of 50 knots, making it the fastest speed to date by a U.S. Navy surface craft using an alternative fuel blend. The LCAC is used to quickly transport equipment, troops and supplies to and from amphibious watercraft.

Down the Road

In July 2012, a "Green Strike Group" will operate during the Rim of the Pacific (RIMPAC) exercise, which directly supports SECNAV's energy goal "to demonstrate a Green Strike Group in local operations by 2012 and sail it by 2016." The Green Strike Group will consist of a nuclear aircraft carrier, and ships and aircraft powered by biofuels. It is intended to test, evaluate, and demonstrate the cross-platform utility and functionality of biofuels, and essentially serves as the "final exam" for the Navy's alternative fuels certification program. The demonstration will also incorporate a number of prototype energy efficiency initiatives, such as solid state lighting, a shipboard energy dashboard, and Smart Voyage Planning. To learn more about these initiatives, go to www.greenfleet.dodlive.mil/energy.

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