USS Greeneville Returns Home Following Deployment

NAVAL BASE POINT LOMA, Calif. (Jan. 30, 2026) – Los Angeles-class fast-attack submarine USS Greeneville (SSN 772) returns to Naval Base Point Loma following a deployment to the U.S. Indo-Pacific Command area of responsibility, Jan. 30, 2026. (U.S. Navy photo by MC2 Rashan Jefferson)
From Commander, Submarine Squadron 11 Public Affairs

NAVAL BASE POINT LOMA – Los Angeles-class fast-attack submarine USS Greeneville (SSN 772) returned to its homeport of Naval Base Point Loma, following a regularly scheduled deployment to the Indo-Pacific region in support of U.S. national security objectives, January 30, 2026.

During the deployment, Greeneville steamed over 49,000 nautical miles while conducting the full spectrum of SSN operations alongside U.S. and Allied forces.

“The return of USS Greeneville marks the successful completion of yet another vital mission for Submarine Squadron 11,” said Capt. Phillip Sylvia Jr., commodore, Submarine Squadron 11. “I am incredibly proud of the Greeneville crew. They operated professionally in challenging environments, proving once again that our undersea forces are the apex predators of the maritime environment and their forward-deployed presence reinforced our commitment to peace through strength.”

The crew of Greeneville relentlessly pursued excellence and operated in a professional manner in support of maritime operations in the Indo-Pacific region, reaffirming the U.S.’ dedication to deterrence, stability, and prosperity.

“The American public and our Allies and partners should rest easy at night knowing that the Greeneville team, along with our brothers and sisters throughout the Submarine Force and the Navy have the watch,” said Capt. Chad Tella, commanding officer, USS Greeneville. “Time and time again, the Greeneville team fearlessly met all challenges head on, not only getting the job done, but exceeding all expectations. The team routinely united in the face of adversity to ensure mission accomplishment, no matter the situation.”

Additionally, while on deployment, Greeneville Sailors completed 695 overall qualifications, and nine officers and 38 enlisted Sailors earned their submarine warfare qualifications.

“Greeneville Sailors performed second to none,” said Senior Chief Logistics Specialist (Submarines) Daniel Dumitrache, chief of boat, USS Greeneville. “Before we deployed, less than 20 Sailors had deployed to the Western Pacific. Now, 165 Sailors know what it takes to deploy and operate at the tip of the spear.”

In between their high tempo undersea missions, Greeneville

conducted a port visit to Busan, Republic of Korea, giving Sailors an opportunity to experience the local culture while building relationships and friendships.

“The port visit to Busan provided a great opportunity to relax following extended at sea operations,” said Dumitrache. “The Republic of Korea (Navy) did an amazing job making us feel welcome. Watching our crew play a game of soccer against the crew of ROKS Jeong Ji (SS 073) was a memorable and impactful experience.”

Commissioned on February 16, 1996, Greeneville is the only vessel in United States naval history named after Greeneville, Tennessee.

Greeneville is one of four Los Angeles-class fast-attack submarines assigned to Commander, Submarine Squadron 11, capable of supporting various missions, including anti-submarine warfare, anti-ship warfare, strike warfare and intelligence, surveillance and reconnaissance.

U.S. Navy Completes Final Flight Test Harpoon Block II Obsolescence Update

An F-15 launches a Harpoon Block II off the coast of California in January 2026. This was final flight test of the Harpoon Block II Update (HIIU) Obsolescence Update program. (U.S. Navy photo)

From Naval Air Systems Command, Patuxent River, Md

NAS Patuxent River, Md.—The U.S. Navy successfully completed the third and final planned flight test of the Harpoon Block II Update (HIIU) Obsolescence Update program Jan. 16, marking a key milestone in modernizing and sustaining the weapon system.

The Precision Strike Weapons (PMA-201) program office, in partnership with Boeing, conducted the test at Naval Air Weapons Station China Lake and the Point Mugu Sea Range in California. The event demonstrated a successful Coastal Target Suppression mission against a representative land target, with all test objectives met based on preliminary assessments.

“This milestone reflects the strength of the integrated government and industry team and their commitment to delivering reliable, relevant capability to the fleet,” said Capt. Sarah Abbott, PMA-201 program manager.

During the mission, the missile executed multiple altitude changes to simulate a coastal engagement. After launch from an F-15 at approximately 12,000 feet above ground level, the missile descended to an initial waypoint altitude of 5,000 feet, then proceeded to the target area and performed a steep terminal dive prior to impact.

The HIIU flight test series consisted of three events designed to progressively validate system performance across mission sets. The first test verified guidance and aerodynamic performance, the second demonstrated engagement of a moving maritime surface target, and the final event confirmed effectiveness against a land-based target—highlighting the weapon's operational versatility.

"This achievement reflects the coordinated efforts of professionals across program management, engineering, logistics, test and evaluation, aircrew, ground support, and range teams, alongside our industry partners," said Bob Cress, SLAM ER/HIIU development team lead.

Following this event, system-level flight testing for the HIIU Obsolescence Update is nearly complete, with initial deliveries planned for later this year.

HIIU builds on the Harpoon's 50+ year legacy by addressing obsolescence items and preparing the weapon to extend production around the world. The U.S. Navy and more than 30 foreign partners use the Harpoon in support of anti-ship and land-strike missions.

USS Truxtun Departs Naval Station Norfolk for Deployment

NAVAL STATION NORFOLK, Va. (Feb. 3, 2026) – The Arleigh Burke-class guided missile destroyer USS Truxtun (DDG 103) departed Naval Station Norfolk for a scheduled deployment on Feb. 3, 2026. (U.S. Navy photo by MC2 Derek Cole)
From Commander, U.S. 2nd Fleet

NORFOLK, Va. – Arleigh Burke-class guided missile destroyer USS Truxtun (DDG 103) departed Naval Station Norfolk for a scheduled deployment on Feb. 3, 2026.

The ship's company includes approximately 300 Sailors, with an additional 26 embarked air wing personnel assigned to the "Valkyries" of Helicopter Maritime Strike Squadron 50.

The ship's independent deployment departure comes after several months of training and maintenance, preparing the ship for a multitude of operations. Truxtun is a multi-mission guided-missile destroyer with air warfare, anti-submarine

warfare, naval surface fire support, and surface warfare capability.

“Truxtun’s recent experiences in the 5th and 6th Fleet areas of operations have sharpened our technical and tactical mastery, translating proven operational readiness into immediate effects,” said Cmdr. James Koffi, commanding officer of Truxtun. “Our presence at sea will not merely be a ‘deployment,’ but a decisive application of *Peace Through Strength.*”

Truxtun’s last deployment concluded in October 2025, where they conducted operations in U.S. 5th and 6th Fleet areas of operations. During this time, the ship successfully worked alongside the Harry S. Truman Carrier Strike Group, the Carl Vinson Carrier Strike Group, the Nimitz Carrier Strike Group, and the HMS Prince of Wales Strike Group in various capacities. Truxtun also represented the U.S. Navy in the multi-national operations Mediterranean Strike and Bright Star, which fostered relationships between various allies and partners.

“The Sailors of USS Truxtun are ready to deploy and accomplish our nation’s work at sea,” said Capt. Bryan Carmichael, commodore, Commander Naval Surface Group Mid-Atlantic. “The combat capabilities that this ship brings to a fight will be ready whenever tasked to deter, and, if necessary, defeat, aggression in defense of America’s interests around the world.”

Truxtun was commissioned on April 25, 2009. The ship is named for Commodore Thomas Truxtun, who was selected as one of the Navy’s initial six captains on June 4, 1798.

“We proudly carry the namesake of Commodore Thomas Truxtun,” said Koffi. “Commodore Truxtun’s primary aim as the commanding officer of USS Constellation, one of the U.S. Navy’s original six frigates, was protecting American commerce in the

Caribbean during a period of deep regional uncertainty in the fledging years of our new nation.”

U.S. 2nd Fleet, reestablished in 2018 in response to the changing global security environment, develops and employs maritime ready forces to fight across multiple domains in the Atlantic and Arctic in order to ensure access, deter aggression and defend U.S., allied, and partner interests.

HII’s Newport News Shipbuilding Completes Successful Builder’s Sea Trials of John F. Kennedy (CVN 79)

NEWPORT NEWS, Va., Feb. 04, 2026 (GLOBE NEWSWIRE) — HII (NYSE: HII) announced today that its Newport News Shipbuilding (NNS) division has successfully completed builder's sea trials of John F. Kennedy (CVN 79), the second Gerald R. Ford-class nuclear-powered aircraft carrier.

Kennedy returned to NNS after testing important ship systems and components at sea for the first time.

"Taking Kennedy to sea is a testament to the grit and determination of the world's finest shipbuilders," said Derek Murphy, NNS vice president of new construction aircraft carrier programs. "Our nation is depending on us to deliver these critical assets that will protect freedom around the world and we're proud to see CVN 79 take another step toward joining the fleet."

The sea trials brought together NNS shipbuilders, John F. Kennedy sailors and Navy personnel to execute the testing and demonstrate ship operations.

CVN 79 continues the legacy of highly capable nuclear-powered aircraft carrier platforms. Ford-class enhancements incorporated into the design support increased operational

efficiency and reduced manning requirements. The Ford class also features a new nuclear power plant, and increased electrical power-generation capacity.

Up-to-seven-year deals to increase annual production of Tomahawk, AMRAAM, SM-3 Block IB, SM-3 Block IIA, SM-6

From RTX

TUCSON, Ariz., Feb. 4, 2026 /PRNewswire/ — Raytheon, an RTX (NYSE: RTX) business, entered into five landmark framework agreements with the U.S. Department of War to significantly increase production capacity and speed deliveries of Land Attack and Maritime Strike variants of Tomahawk, AMRAAM® missiles, Standard Missile-3® Block IB interceptors (SM-3 IB), Standard Missile-3® Block IIA interceptors (SM-3 IIA), and Standard Missile-6® (SM-6).

As global demand for these precision munitions continues to

grow, these up-to-seven-year agreements establish frameworks to build on the company's previous investments to expand production. Under the frameworks announced today, RTX will increase annual production of Tomahawks to more than 1,000, AMRAAMs to at least 1,900, and SM-6 to more than 500. RTX will also increase production of SM-3 IIA and accelerate production of the SM-3 IB. Many of these munitions will grow 2 to 4 times their existing production rates.

With the Department of War's strong commitment to strengthening the defense industrial base and creating American jobs, RTX will continue to make investments in technology, facilities and our workforce to reach and sustain this historically high production rate.

"These agreements redefine how government and industry can partner to speed the delivery of critical technologies and are a direct result of the administration's Acquisition Transformation Strategy and commitment to deliver the best technologies faster," said RTX CEO and Chairman Chris Calio. "We are proud to support the department's Arsenal of Freedom to ensure the United States and its allies and partners have the decisive edge – now and in the future."

RTX has invested heavily in capacity expansion to accelerate production of several critical munitions and will continue investing in capacity expansion and production acceleration projects. Production under these framework agreements will be completed at Raytheon facilities in Tucson, Ariz., Huntsville, Ala., and Andover, Mass.

The company investments associated with these framework agreements have been contemplated in RTX's recently announced financial outlook for 2026. The long-term agreements incorporate a collaborative funding approach designed to preserve upfront free cash flow, allowing RTX to invest confidently to meet long-term demand.

CRITICAL MUNITIONS FOR U.S. AND ITS ALLIES AND PARTNERS

Tomahawk cruise missile

A precision weapon launched from ships and submarines and can strike targets precisely from 1,000 miles away, even in heavily defended airspace. U.S. and allied militaries have flight tested the Tomahawk over 550 times and used it in an operational environment more than 2,300 times. It is routinely the first option employed by U.S. forces to target hostile forces anywhere in the world.

AMRAAM

The world's most widely deployed, air-to-air missile. Since 2024, Raytheon has been producing the fifth-generation AMRAAM, featuring advanced guidance, software-defined capabilities and enhanced electronic protection for highly contested combat environments. In service with more than 40 allies and partners, AMRAAM is integrated across fourth and fifth generation aircraft and serves as the primary interceptor for NASAMS, supporting both air-to-air and ground-based air defense. Production nearly doubled in 2025 from 2024 and performance has been proven through more than 6,000 test shots and 13 air-to-air combat victories.

SM-3 IB

A combat proven interceptor uniquely designed for exo-atmospheric intercept of short- to intermediate-range ballistic missiles with hypersonic hit-to-kill accuracy. It can be launched from both ships and land-based sites. In April of 2024, SM-3 IB was first used in combat to intercept Iranian ballistic missiles headed toward Israeli targets.

SM-3 IIA

An interceptor created in a cooperative development program between the U.S. Missile Defense Agency, the Japan Ministry

of Defense and their industry partners. The interceptor features larger rocket motors and an enhanced kinetic warhead compared to its predecessors, allowing it to engage threats faster and protect larger regions from short- to intermediate-range ballistic missile threats.

SM-6 missile

Standard Missile-6 is the only missile that supports anti-air warfare, anti-surface warfare and sea-based terminal ballistic missile defense in one solution, and it’s enabling the U.S. and its allies and partners to cost-effectively increase their projected force. SM-6 has been successfully fired from various U.S. Navy ships and launchers on land.

Marine Corps fast-tracks contract for new Precision Attack Strike Missile

The Navy’s Air Test and Evaluation Squadron (HX) 21 launch a Long Range Attack Missile (LRAM) from an AH-1Z off coast of Virginia in late 2025. This demonstration paved the way for the Precision Attack Strike Munitions program (PASM), bringing cost-effective, long-range precision strikes to the USMC AH-1Z missions. (U.S. Marine Corps photo)
From Naval Air Systems Command, Jan 30, 2026

NAS PATUXENT RIVER, Md. – The Department of Navy announced the $86.2 million contract award of the Precision Attack Strike Munition to L3Harris Technologies Jan 30, a critical component of the Marine Corps’ vision for enhancing the lethality and survivability of its rotary-wing assets.

PASM will provide the Marine Corps with a cost-effective, longer-range, precision weapon that can deliver diverse effects (kinetic or non–kinetic) from AH-1Z aircraft in land and sea-based environments.

Over the past several years, the Marine Corps conducted a Joint Capability Technology Demonstration (JCTD) for the Long-Range Attack Munition (LRAM). The tests successfully proved

the technology’s capability for a low-altitude, rotary-wing aircraft to perform offensive anti-surface warfare and maritime strikes. These demonstrations informed the department’s decision to award the contract.

“We are proud to partner with L3Harris Technologies to deliver a system that will provide a decisive advantage to Marine Corps pilots and support their missions worldwide,” said Rear Adm. Tony Rossi, who oversees the Program Executive Office for Unmanned Aviation and Strike Weapons (PEO (U&W)).

PEO (U&W)’s Direct and Time Sensitive Strike Weapons program office (PMA-242) awarded the contract under an Other Transaction Agreement/Authority (OTA) – a contract vehicle used by the government to streamline research and development and prototype development.

“The use of an OTA contract is a key part of this strategy, designed to rapidly prototype and field a capability that’s essential for operations in contested environments and against advanced adversaries,” said. Capt. Lindsey Buzzell, PMA-242 program manager.

Under the contract, L3Harris Technologies will deliver all units, manuals, training, support equipment, and test equipment for AH-1Z by end of fiscal year 2027.

PMA-242 is the Direct and Time Sensitive program office for the Navy and Marine Corps.

HII Hosts U.S. Marine Corps

Leaders at Ingalls Shipbuilding

PASCAGOULA, Miss., Feb. 03, 2026 (GLOBE NEWSWIRE) — HII (NYSE: HII) hosted U.S. Marine Corps Gen. Bradford Gering, assistant commandant, and fellow U.S. Marine Corps officers at the company's Ingalls Shipbuilding division Thursday. The Marines met with Ingalls leadership and toured the shipyard, including stops at two of the five amphibious warships currently under construction, *Bougainville* (LHA 8) and *Harrisburg* (LPD 30).

"We are honored to host Marine Corps leadership and showcase the critical role our Ingalls shipbuilders play in delivering the amphibious ships that support Navy and Marine Corps missions worldwide," said Brian Blanchette, Ingalls Shipbuilding president. "The amphibious ship program remains a top priority for our team, and we value the opportunity to demonstrate the skill and dedication our shipbuilders bring to every ship we build."

Ingalls has a long-standing history of building amphibious warships, and the collaboration between Ingalls Shipbuilding,

the U.S. Navy and the Marine Corps was on full display during the visit.

Commenting on the tour, Gering highlighted the importance of amphibious warships.

“The Navy and Marine Corps team relies on these ships for a broad range of missions from peacekeeping and deterrence to combat operations and humanitarian assistance,” Gering said. “Programs like the LHA and LPD are vital to enabling Marine Corps readiness and ensuring our ability to respond quickly to emerging challenges.”

Ingalls currently has two LHAs under construction including *Bougainville* (LHA 8) and *Fallujah* (LHA 9) and three Flight II LPDs under construction including *Harrisburg* (LPD 30), *Pittsburgh* (LPD 31) and *Philadelphia* (LPD 32). Additionally, in September 2024, the Navy awarded Ingalls a contract for the construction of three *San Antonio*-class amphibious transport dock ships (LPD 33, LPD 34 and LPD 35) and a contract modification for the fifth *America*-class amphibious assault ship, *Helmand Province* (LHA 10).

U.S. Demonstrates Advanced Submarine Combat Control System Technology for UK Counterparts

By AUKUS Integration & Acquisition, Feb. 4, 2026

GROTON, Connecticut – As part of the AUKUS trilateral security partnership, the U.S. Navy recently demonstrated its advanced AN/BYG-1 submarine combat control system to sailors and industry members from the United Kingdom (UK). The AN/BYG-1 developed under a joint U.S. / Australian program office and is used aboard both nations' submarines.

Representatives from the UK, including the Royal Navy, government, and industry, visited Naval Submarine Base New London in Groton, Conn., in November 2025 to observe U.S. Navy

Sailors from Los Angeles-class nuclear-powered fast-attack submarine USS Hartford (SSN 768) operating the AN/BYG-1 combat control system at the shore-based virtual Submarine Multi-Mission Team Trainer (SMMTT).

This capability demonstration supports the integration of the AN/BYG-1 into the future SSN-AUKUS which is being designed by the UK and will be built and operated by both the Royal Navy and the Royal Australian Navy under the AUKUS program, the trilateral security agreement between Australia, the UK and U.S. to deliver a nuclear-powered, conventionally armed submarine capability to Australia.

Currently, the U.S. Navy and Royal Australian Navy operate the AN/BYG-1 aboard their submarines. Including the system in the baseline SSN-AUKUS design highlights the interconnectivity and interoperability of the three nations' attack submarine fleets.

The AN/BYG-1 links sensor inputs and controls submarine combat operations, including targeting and firing torpedoes and missiles. The system integrates tracking of other submarines and surface ships, improving situational awareness for the submarine's crew. Unlike combat control systems of the past, the AN/BYG-1 utilizes commercial off-the-shelf technology and software updates to enable easier upgrades over the life of the submarine.

During the first days of the demonstration, U.S. Navy Sailors and instructors briefed the UK contingent on the AN/BYG-1 system. Following the briefs, the group observed crew from Hartford operating the version of AN/BYG-1 recently installed on their submarine. After observing Hartford's crew, UK personnel took the controls in the SMMTT and spent six days operating the system.

"We are extremely grateful to the crew of USS Hartford and the

U.S. Naval Submarine School, who provided us with a fantastic demonstration of submarine warfighting that gives the UK a greater understanding of the AN/BYG-1 system. This is an important milestone for the Royal Navy and demonstrates the significant progress made in submarine combat system capability collaboration across all of the AUKUS partner nations," said Cmdr. Rob Richards, RN, AUKUS Combat System Technology Insertion. "The UK is committed to integrating this combined U.S./Australian system in SSN-AUKUS and driving forward our true AUKUS ambitions of future interoperable, collaborative submarine forces."

"The great thing about systems like BYG-1 is that once you're trained and proficient, you can go to any submarine in the Navy and be familiar with your station and the system you are operating," said Lt. Scott Buckman from the Modernization Training Team. "Ultimately, with three nations operating variations of the system, we could see personnel from the three nations serving on each other's boats, greatly enhancing interoperability, training, and ultimately improving our collective warfighting capabilities."

Australia's acquisition and employment of nuclear-powered attack submarines under AUKUS Pillar I directly supports U.S. and allied efforts to ensure a favorable balance of power in the Western Pacific through deterrence. Increasing the number of partner submarines in the region expands combined undersea capabilities and builds peace through strength while enhancing the U.S. force posture in the Indo-Pacific. The trilateral program bolsters readiness and undersea warfighting capability by growing submarine interoperability, expanding access and sustainment infrastructure and ensuring seamless operations during crises.

The AUKUS Integration and Acquisition program office, within the Department of the Navy, is responsible for executing the trilateral partnership to help

Australia acquire conventionally armed, nuclear-powered attack submarines while setting the highest nuclear stewardship standards and continuing to maintain the highest nonproliferation standard.

DMS Celebrates Ribbon Cutting for New Pump Test Loop at Chesapeake Facility

Rep. Jen Kiggans (center) prepares to cut the ribbon at DMS' new pump test loop. *Photo credit: DMS*

Defense Maritime Solutions (DMS) marked a major milestone in its commitment to supporting the shipbuilding industry with a ribbon cutting ceremony for its newly installed pump test loop

at the headquarters in Chesapeake, Virginia.

The event brought together key regional and federal stakeholders, including Rep. Jen Kiggans (R-Va.), representatives from NASSCO, Military Sealift Command, the city of Chesapeake and the Hampton Roads Alliance.

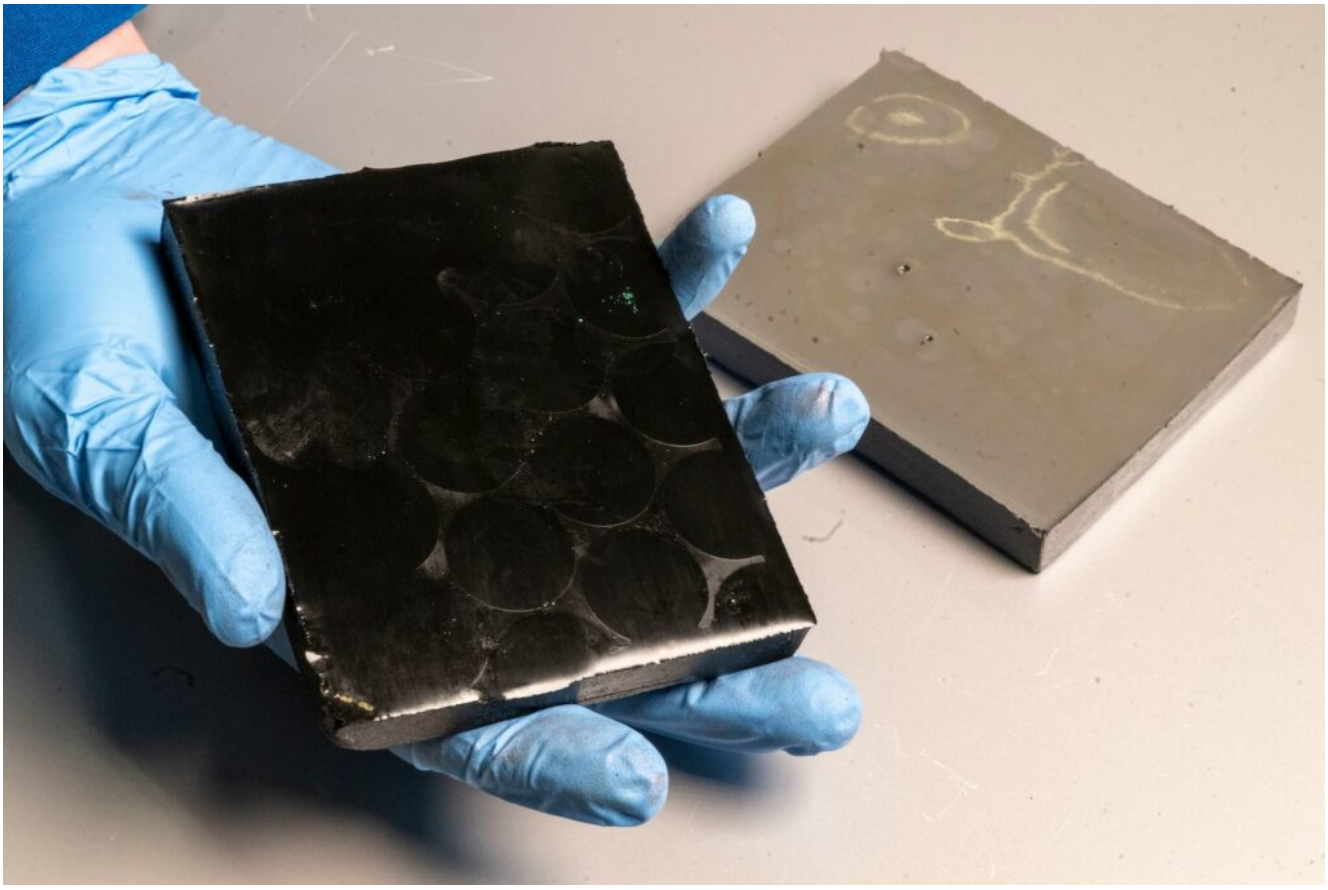
The addition of the pump test loop significantly enhances DMS's ability to support vessels currently under construction. The system uses a closed-loop water circuit to verify that pumps meet required flow rates and operate without excess vibration or heat. By conducting full functional testing onsite, DMS can accelerate delivery of approved pumps to local shipyards, reducing turnaround times and strengthening the regional maritime supply chain.

"Our new test loop represents an important investment in both quality assurance and efficiency. Having this capability in Chesapeake allows us to better serve our shipyard partners and ensure the reliability of critical components going aboard new vessels." said DMS President Noble Davidson.

The system includes two separate testing sections: one designed for large capacity pumps and another for smaller units. Each section can operate independently, allowing DMS to test different types of pumps at the same time without interference, a feature that increases efficiency and throughput.

The ceremony highlighted DMS's role in advancing innovation in the maritime defense industry, as well as the continued growth of maritime manufacturing and support services in Hampton Roads.

NRL: Breakthroughs in Testing Solid-Fuel Ramjets Advance Research



Featured are composite fuel slabs at the U.S. Naval Research Laboratory's (NRL) Combustion Lab in Chesapeake Beach, Maryland, Jan. 15, 2026. The fuel slabs contain a polymer binder, featuring carbon black (left) to increase its absorption of radiant energy and aluminum (right) to increase its energy density. Researchers and engineers at NRL use these fuel slabs with an optically-accessible solid-fuel slab burner to perform combustion experiments at conditions relevant to solid-fuel ramjet flight. (U.S. Navy photo by Jonathan Sunderman)

Jan. 29, 2026 | By Jameson Crabtree, U.S. Naval Research Laboratory

Scientists at the U.S. Naval Research Laboratory are developing the next generation of solid-fuel ramjet

propulsion, addressing one of the field’s most persistent challenges: understanding and predicting what happens inside an operating combustor.

NRL scientists have figured out how to “see inside” one of the most extreme engines ever built, turning guesswork into knowledge and making future long-range, high-speed flight more achievable than ever before.

A solid-fuel ramjet is an air-breathing engine that uses solid fuel rather than liquid, offering high energy density and mechanically simple propulsion by burning the fuel with oxygen from the air to produce thrust. By drawing oxygen from the atmosphere rather than carrying an oxidizer on board, solid-fuel ramjets can carry more fuel in the same volume and fly farther than traditional rocket systems.

“If you replace all the oxidizer and instead use oxygen from the air to burn your fuel, you can increase range by up to 200 to 300% in the same form factor,” said Brian Bojko, a combustion scientist at NRL.

Despite that promise, widespread adoption has been slowed by the extreme internal environment of solid-fuel ramjets, where high temperatures, soot and rapidly evolving flow structures prevent traditional probes from accessing critical data. Unlike liquid or gaseous fuels, solid fuels release energy through surface regression and often produce a complex mixture of combustion products, making it far more difficult to control burning rates and predict performance. This is why understanding and predicting what happens inside an operating combustor is so important.

“In solid-fuel ramjets, you don’t have direct control over the mass flow rate like you do with liquid systems,” Bojko explained. “The heat from combustion actually drives the gasification of the solid fuel, so pressure, temperature and airflow all feed back into how the engine behaves.”

Without detailed measurements of flame temperature, fuel regression and fuel-vapor transport, designers have historically relied on trial-and-error approaches.

“A lot of the design has been kind of Edisonian,” Bojko said. “You take a guess, test it and iterate. But without seeing the physics inside the combustor, it’s hard to know if you’re getting the right answer for the right reason.”

At the same time, computational approaches such as Reynolds-Averaged Navier–Stokes and Detached Eddy Simulation have been limited by a lack of high-quality experimental data for validation.

RANS, DES and`Large Eddy Simulation represent increasing levels of physical realism in turbulence simulation, where more turbulent structures are directly resolved rather than modeled. Moving from RANS to DES to LES brings simulations closer to the true flow physics, especially for unsteady flows, but at a significantly higher computational cost. Reynolds-Averaged Navier–Stokes models capture most of the turbulence and are computationally efficient but less accurate for unsteady flows. Detached Eddy Simulation resolves large turbulent structures while modeling smaller ones, balancing accuracy and cost. LES resolves most turbulent motion directly, offering the highest accuracy at the highest computational expense.

“With only a few pressure or temperature points, you can match a simulation to an experiment and still be wrong,” Bojko said. “Optical access lets us validate the flame structure, recirculation zones and combustion species directly.”

Seeing Flame Temperature in Real Time

To address these gaps, researchers employed optical diagnostics capable of operating in the harsh, particle-laden environment of a solid-fuel ramjet combustor. Measuring flame temperature is especially important, Bojko said, because

models often assume combustion efficiency rather than measure it.

“These diagnostics give us new data we simply didn’t have before,” said David Kessler, a senior computational scientist at NRL. “They allow us to measure gas-phase species and temperatures in an environment where traditional probes just don’t work.”

The chemistry behind how solid fuels decompose and feed the flame is just as important as measuring the flame itself, according to researchers. As heat from the flame feeds back into the fuel surface, the solid polymer undergoes phase change and chemical breakdown, releasing a complex mixture of gaseous hydrocarbons that sustain combustion.

“You have this continuous feedback loop,” said Brian Fisher, a combustion research engineer at NRL. “The flame heats the fuel, the fuel decomposes into gas-phase species, and those species then mix with the air and keep the flame going. It’s a coupled thermal, chemical and fluid-dynamic process, and that’s what makes solid-fuel ramjets both powerful and challenging to predict.”

Mapping Fuel Regression and Validating Models

Understanding how quickly the solid fuel surface recedes, known as fuel regression, is critical because it directly governs thrust and performance. The team combined experimental diagnostics with high-fidelity simulations to resolve heat feedback to the fuel surface, a key driver of regression.

“One of the biggest things you need to capture is the heat transfer back to the solid fuel,” Bojko said. “RANS can give you an OK answer, but it doesn’t resolve the fundamental processes as well as DES or Large Eddy Simulation. Those higher-fidelity approaches cost more computationally, but they give you a much better picture of what’s happening.”

Visualizing Fuel Vapor Before It Burns

For the first time, the researchers also visualized fuel vapor released from the solid surface before ignition, revealing how complex hydrocarbon species mix and evolve prior to combustion. Solid-fuel ramjets commonly use hydroxyl-terminated polybutadiene, a long-chain polymer that breaks down into many different gaseous species.

“When HTPB decomposes, you don’t know what species are coming off the surface, and those species dictate the combustion mechanism,” Bojko said. “They change with temperature, pressure and heat flux, so being able to characterize them is critical to understanding the underlying mechanisms across different flight conditions.”

In parallel, NRL researchers are investigating advanced composite fuels designed to increase the energy density of solid fuel in the same volume.

“We’re interested in adding energetic additives, like metal particles, into polymer fuels to increase their energy density,” said Clayton Geipel, a combustion research engineer at NRL. “As the fuel burns, those particles are released into the flame and ignite, giving you more energy from the same volume of fuel. That directly translates into greater potential range for future systems.”

“You want to jam as much energy content into that block of fuel as you can while still having a reasonable rate of combustion; that’s the challenge,” said Albert Epshteyn, materials scientist at NRL.

Although metals can have slightly lower energy per unit mass than hydrocarbons, their much higher density allows more total energy to be packed into the same volume, a critical advantage for compact, long-range systems.

Reducing Risk and Accelerating

Together, these diagnostics and simulations transform solid-fuel ramjet combustion from a largely inferred process into a measurable, predictable system. The validated models allow researchers to conduct design iterations computationally before moving to costly experiments.

“Our main objective is to reduce risk,” Bojko said. “If we have validated computational models, we can do design iterations much more efficiently in terms of cost and time and narrow down the physics before we ever go to full-scale testing.”

Kessler emphasized the broader impact.

“NRL is developing technologies that help accelerate the transition of solid-fuel ramjets, technology that can significantly increase the range of next-generation high-speed systems,” he said.

Building on that foundation, the team is now focused on bridging the gap between small-scale laboratory experiments and real-world propulsion systems.

“All of our work right now happens at small-scale facilities in idealized, optically accessible geometries,” Geipel said. “That’s what allows us to make detailed measurements, but there are still important questions about how those results apply to a full-scale, enclosed ramjet.”

While small-scale experiments reveal detailed physics, scaling those results to full-size engines remains a central uncertainty in the field. The next phase of the research will focus on extending these validated tools and models to larger, more representative test configurations. This intermediate step preserves diagnostic access while introducing greater geometric and physical realism. That progression is designed to ensure the physics and chemistry observed in the lab translate reliably to operational propulsion systems.

By integrating optical diagnostics, detailed chemistry and validated simulations across multiple scales, the research provides the propulsion community with tools to reduce uncertainty, shorten development timelines and enable future high-speed air-breathing propulsion technologies.