

2025

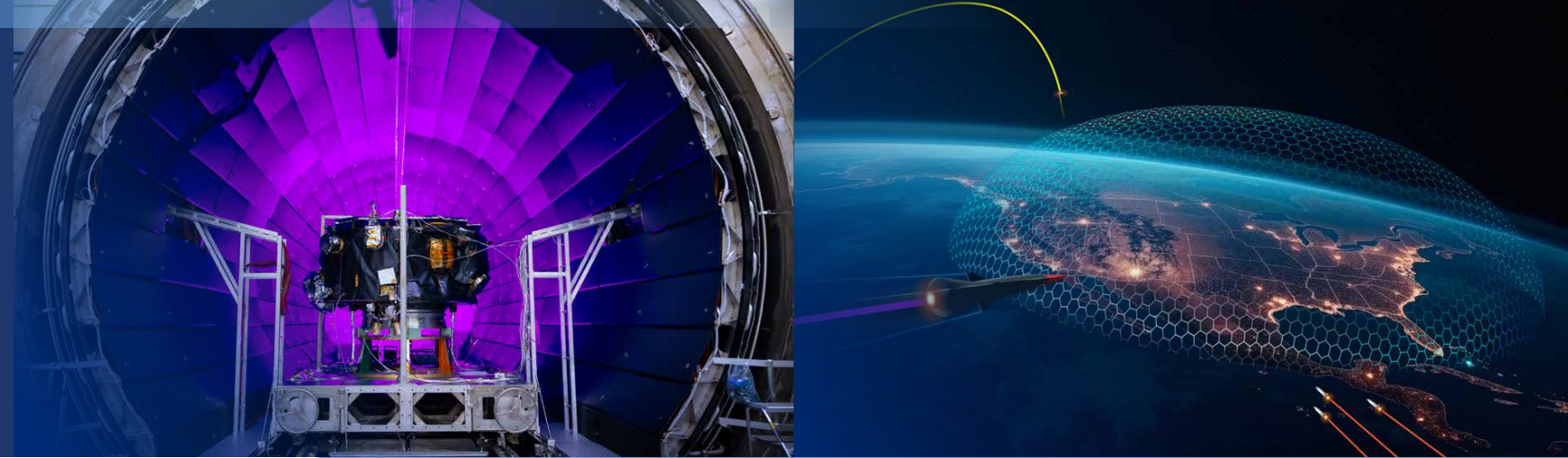
ANNUAL REPORT

THE JOHNS HOPKINS APPLIED PHYSICS LABORATORY



The Johns Hopkins Applied Physics Laboratory leverages world-class talent and facilities to conceive, develop, and rapidly prototype critical innovations across multidomain missions spanning deep sea to space. Our multidisciplinary teams integrate broad expertise with systems and mission engineering to deliver proven, effective end-to-end solutions that are quickly fielded and transitioned for development at scale. Many of these capabilities, coupled with our forward-looking research, serve as essential underpinnings for transformative future systems to ensure the nation's preeminence.

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DIRECTOR'S MESSAGE

APL Director David M. Van Wie leads a panel discussion with APL leaders Vishal Giare, Lisa A. Blodgett, Andrew S. Mara, and Robert D. Braun on the strategic challenges facing the nation and the Laboratory's role in addressing them. The discussion highlighted how APL is aligning its technical strengths, partnerships, and mission focus to deliver innovative solutions in an increasingly complex security environment.



Today, we find ourselves in the midst of a decisive decade, one marked by a multipolar Great Power Competition, rapidly evolving forms of warfare, emerging new threats, and a dynamic domestic landscape.

It is during challenging times like this that the capabilities of the Applied Physics Laboratory are most needed. Our sponsors have let us know that our innovations and contributions continue to have significant impact, thanks to our focus on our mission and on the security and well-being of our nation. This is made possible because of our commitment to our core purpose of making critical contributions to critical challenges, and by leveraging the insights and abilities of our dedicated staff members.

From the newest young engineer to our most senior leaders, APL's staff remains committed to seeking and addressing strategic challenges that align our deep experience and core competencies with national priorities. On the pages of this annual report, you'll read how our staff envisioned and delivered new technologies and capabilities to the U.S. Naval Forces and the Joint Force, NASA, and the Intelligence Community. Solutions are provided for highly complex problems in diverse areas such as air and missile defense, electromagnetic maneuver warfare, AI, cyber, and one-of-a-kind spacecraft engineering. Our engineers, scientists, and analysts joined together to counter emerging and increasingly unpredictable unmanned systems threats in the air and in the water, advance autonomy for operational advantage, and develop new materials science, all while strengthening the partnerships that transform our work into impact.

Working with collaborators in government, industry, and academia, we pursued research exploring effective ways to protect critical infrastructure, harness the power of human-machine teaming, tap the potential of biotechnology and quantum computing, and expand the utilization of space. Our staff accomplished these feats thanks in no small part to the dedication of our enterprise service colleagues, who enable the important work of the Laboratory every day.

I began my tenure as APL's ninth director in July, honored to be entrusted with the leadership of such an incredible organization, one with which I have spent my entire professional career. This annual report spans our staff's accomplishments during my first six months in this role, as well as those made during the final six months of our eighth director, Ralph Semmel, who for 15 years led APL in dedicated and impactful service to our sponsors and the nation.

We carry the momentum of not just our recent past but our eight decades of service to the nation into the year ahead, approaching every critical challenge as One APL, and one team, with one purpose. Every day I come to the Laboratory, I am excited to see our collective excellence turned into action through new ideas, initiatives, solutions, and insights, and I am confident that APL will continue to deliver critical contributions to critical challenges facing our nation.

— DAVID M. VAN WIE

A large naval ship, the USS Roosevelt (DDG 80), is shown transiting the Suez Canal. The ship's complex superstructure, featuring multiple radar masts and missile launchers, is prominent. A large missile is mounted on a launcher in the foreground. The ship is moving through the water, with the canal's bridge visible in the background under a clear blue sky.

DEFENDING THE **NATION**

From the seas to the skies, cyberspace, and deep space, the challenges facing U.S. forces today span every domain. Whether enabling rapid planning for fleet protection, strengthening air and missile defenses, or advancing electronic warfare capabilities, APL applies deep technical expertise to design, integrate, prototype, and accelerate capabilities that help the nation anticipate threats and act decisively — making critical contributions toward a more agile, resilient, and integrated national defense posture.

USS Roosevelt (DDG 80) transits the Suez Canal, demonstrating the forward presence and maritime security missions carried out by Aegis destroyers in the U.S. Central Command area of responsibility. APL helps the Navy strengthen fleet defense by advancing integrated air and missile defense capabilities through combat systems engineering, modeling and simulation, and mission-focused analysis. Credit: U.S. Navy



Sailors assigned to the Arleigh Burke-class guided-missile destroyer USS Carney (DDG 64) stand watch in the ship's Combat Information Center during an operation to defeat a combination of Houthi missiles and unmanned aerial vehicles. APL provided timely analyses that drove strategic decision-making and responsive mission planning in these conflicts. Credit: U.S. Navy



The Arleigh Burke-class guided-missile destroyers USS Ross (DDG 71), USS Gonzalez (DDG 66), and USS Mason (DDG 87) conduct a breakaway during the Titans of the Sea Presidential Review. During the Houthi conflict involving the USS Mason, APL delivered two capabilities that enabled Navy crews to adapt swiftly to shifting threats, optimize force posture, and continuously refine system employment under combat conditions. Credit: U.S. Navy

Enabling Rapid Planning and Fleet Defense Operations

The beginning of Red Sea hostilities in late 2023 marked the most persistent air and missile threat environment faced by U.S. naval forces in recent history. In the intervening years, with Navy ships such as the USS Mason, USS Arleigh Burke, and USS Carney facing sustained missile and drone attacks, APL leveraged decades of experience in the technology and system development associated with naval air and missile defense and delivered rapid, high-impact technical solutions that proved vital to U.S. naval forces during sustained combat operations in the Red Sea.

Effective coordination across fleet platforms, combatant commands, warfare centers, and government-industry teams ensured APL insights informed real-time and future operations during persistent missile and drone attacks in the Red Sea. Two complementary capabilities played critical roles: APL's Cerberus collaborative planning tool and the Air and Missile Defense Real World Cell. Cerberus, a prototype that aids in refining mission plans to enable more specific reach-back analysis requests and evaluation, was developed with the Missile Defense Agency (MDA) and deployed in 2025 aboard a destroyer and an afloat Maritime

Operations Center. In parallel, the Real World Cell provided around-the-clock support to deployed Aegis platforms, delivering tailored mission packages, post-event analyses, and technical guidance that directly shaped fleet operations and theater-level decisions.

"As today's threats advance and adversary tactics evolve, our team's work allowed operators to rapidly adapt," said Vishal Giare, head of APL's Air and Missile Defense Sector. "The Real World Cell and Cerberus fuse decades of engineering into timely options that enable sailors to safely execute their missions."

These efforts enabled Navy crews to adapt swiftly to shifting threats, optimize force posture, and continuously improve system use under combat conditions. Cerberus earned cyber and Naval Information Warfare Systems Command physical security certifications in the spring of 2025, clearing the way for broader fleet deployment. Meanwhile, the Real World Cell responds to events — one being the June 2025 attack on Israel — with rapid analysis, informing critical defensive configurations and after-action reviews. APL engineers provide the Navy with assessment, analysis, and recommendations for operational ship actions in the region, helping to combat the evolving threats. Together, these initiatives showcase APL's ability to pair long-term strategic vision with real-time responsiveness — bringing together digital planning, combat system expertise, and deep operational insight to defend U.S. and allied assets in an ever-evolving threat landscape.

As the U.S. and allies face continuing, and potentially escalating, conflict in the Middle East, APL will continue to play a critical role in ensuring timely analysis to drive strategic decision-making and responsive mission planning to protect U.S. and allied forces.

Quick Response

As the U.S. and its allies face persistent and potentially escalating threats in the Middle East, APL provides timely analyses that drive strategic decision-making and responsive mission planning. In 2025 alone, this included completing post-event assessments and threat engagement reconstructions within hours as well as delivering (through the Real World Cell) more than 100 mission packages and 50 detailed, data-backed analyses that shaped Aegis missile defense system employment and guided operational decisions.



“The Real World Cell and Cerberus fuse decades of engineering into timely options that enable sailors to safely execute their missions.”

— Vishal Giare, Air and Missile Defense Sector Head

Strengthening Force Readiness

Backed by thorough engineering, research, testing, modeling, and simulation, APL innovations are improving the speed, accuracy, and resilience of the nation's air and missile defense systems and its strategic deterrent. Key to this work are live tests and simulations to validate system performance under realistic conditions. From intercept tests and layered defense assessments to exercises involving advanced sensors and cross-domain coordination, these trials strengthen the integrated networks that protect U.S. forces, allies, and the homeland against evolving threats.



An F/A-18E Super Hornet, attached to Strike Fighter Squadron (VFA) 14 and equipped with the AIM-174B Beyond Visual Range Air-to-Air Missile, prepares to launch off the flight deck of the Nimitz-class aircraft carrier USS Abraham Lincoln (CVN 72) during exercise Northern Edge 2025. APL provided technical expertise to enable integration of the AIM-174B into operational service. Credit: U.S. Navy



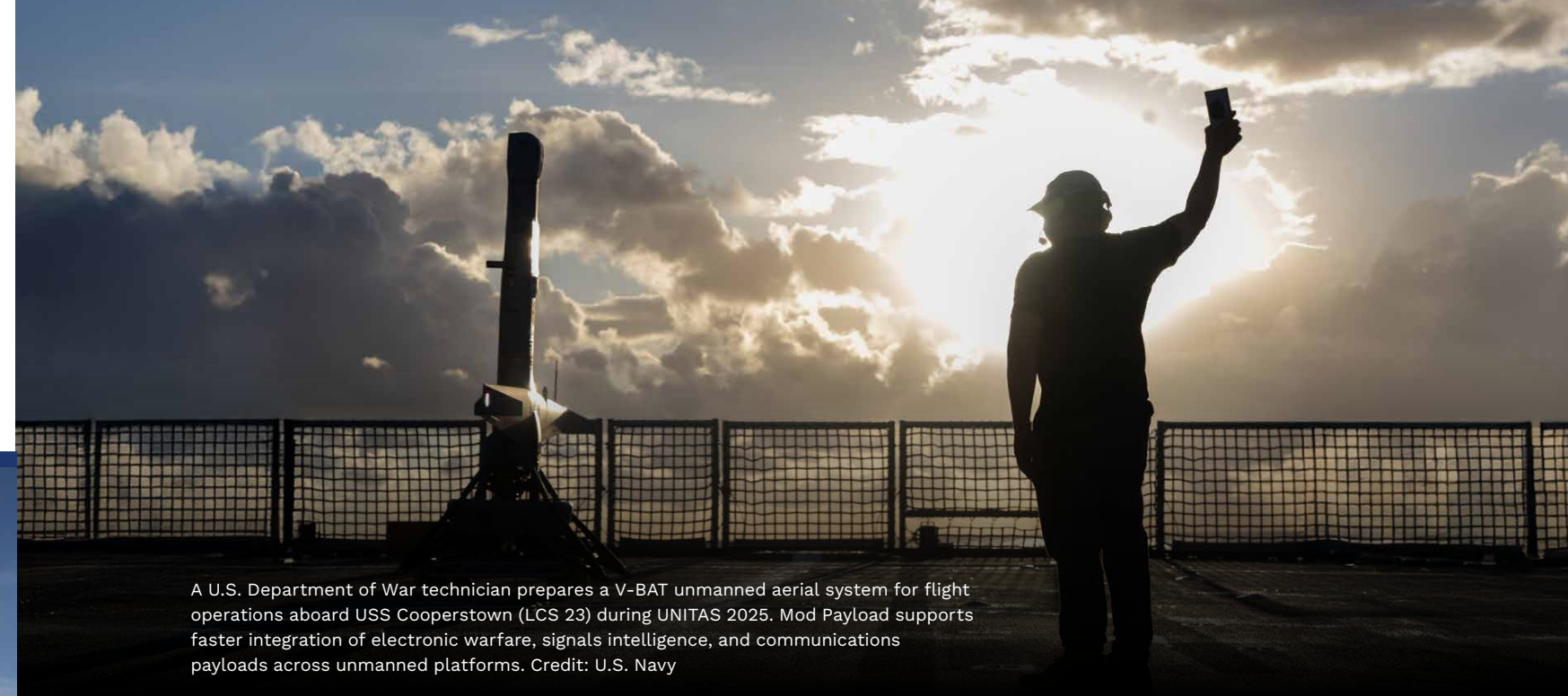
Rocket Lab's Electron launch vehicle lifts off from Wallops Flight Facility carrying a government test payload developed and integrated by APL, demonstrating a lower-cost approach for national defense test and evaluation using commercial launch services. Credit: Rocket Lab

■ APL completed end-to-end analysis and assisted with the integration of the Navy's newest long-range air-to-air missile — the AIM-174B, an air-launched configuration of the proven Standard Missile-6 — into operational service. A Laboratory team adapted the SM-6 for launch from a fighter jet instead of a ship, which required a redesign of thermal management, structural, and software interfaces to survive the extreme vibratory and aerodynamic loads of air release. The result is an asset the Navy describes as its longest-range and most capable air-to-air missile.

■ The Naval Modular Missile (NMM) program made significant progress toward developing a next-generation, multimission interceptor to enhance fleet capacity, adaptability, and long-range lethality through a modular, open-systems architecture that supports rapid fielding by a joint government-industry-Laboratory team. In 2025, the NMM program — led by APL in conjunction with Program Executive Office for Integrated Warfare Systems — significantly advanced this vision by refining top-level requirements and continuing work on an open, government-owned digital reference architecture that promotes rapid technology integration and industry competition.

■ MDA and APL successfully demonstrated a new, lower-cost approach to national missile defense testing and evaluation with the November launch of a payload aboard Rocket Lab's Electron vehicle in the HASTE configuration. The suborbital mission, developed under an MDA-funded effort known as Project Budget Launch of Affordable Suborbital Targets, or BLAST, marks the first time a payload of this type has flown on a commercially operated launch vehicle. The vehicle achieved its planned trajectory and met all objectives involving payload deployment, telemetry, and flight performance, validating that commercially available launch systems can be adapted for government test missions traditionally requiring custom-built boosters. The development cycle for missile defense test vehicles traditionally stretches several years. The BLAST team compressed end-to-end development to 18 months — and delivered the full mission including launch vehicle, payload development, integration, and launch operations.

■ In September 2025, the Navy's Strategic Systems Programs conducted test flights of unarmed Trident II D5 Life Extension missiles, including one carrying the APL-designed and -built Enhanced Inert Head (EIH) reentry body, which successfully flew for the second time. The EIH continues to meet its objective of cost-effective instrumentation and data collection, and its success has led to additional projects, including the Plasma Experiment and Ground Station System experiment, which is scheduled to fly in April 2027.



A U.S. Department of War technician prepares a V-BAT unmanned aerial system for flight operations aboard USS Cooperstown (LCS 23) during UNITAS 2025. Mod Payload supports faster integration of electronic warfare, signals intelligence, and communications payloads across unmanned platforms. Credit: U.S. Navy

Advancing Electronic Warfare

APL is developing technologies to provide warfighters with timely, reliable information in contested environments. Some of these tools and techniques enable service members to quickly detect, interpret, and respond to electromagnetic threats — such as jamming or signal interference — that complicate field operations.

In 2025, the Department of War updated its Modular Payload Design Standard, marking a significant evolution in the way electronic warfare, signals intelligence, and communications payloads are conceived, integrated, and sustained across unmanned and dismounted platforms.

Conceived under U.S. Special Operations Command to bring modularity to unmanned aerial systems, the standard — also known as Mod Payload — was developed by a government and industry team led by APL, with significant contributions from the Lab throughout the effort. The standard's reach has steadily expanded, and it has been implemented by a range of small unmanned vehicles and dozens of payloads across the military.

The Mod Payload standard defines requirements to achieve true plug-and-play interoperability between systems. By outlining a uniform architecture for both payloads and host platforms, the standard drives down development costs, shortens integration timelines, and enhances maintainability in austere environments — all while promoting system reliability and affordability.

“As unmanned and autonomous systems grow ever more sophisticated, maintaining seamless interoperability for our warfighters is paramount,” said APL Assistant Director for Programs Lisa A. Blodgett. “The Mod Payload standard not only streamlines interoperability but also enables rapid fielding of innovative technology to give our forces a decisive advantage in dynamic and contested environments.”

Recently expanded to include unmanned surface vehicles and dismounts, Mod Payload is approved for unlimited public release, which streamlines access for industry and allied partners, fosters broader adoption, and accelerates innovation across the defense community. Shield AI, a defense technology firm and the platform integrator for the V-BAT vertical takeoff and landing unmanned aerial system found on nearly every class of Navy ship and all seven Marine Expeditionary Units, cited Mod Payload as a critical factor in the platform's success.

Another force enabler boosted by APL innovation is the AN/ALQ-249 Next Generation Jammer Mid-Band (NGJ-MB) system, an electronic warfare system that allows Navy Growlers to conduct airborne electronic attacks by disrupting, denying, and degrading enemy early-warning, air defense, and communications systems with increased jamming capability at longer ranges. Navy officials describe the NGJ-MB as a “quantum leap in capability over legacy systems,” with greatly increased power, target flexibility, and jamming techniques compared to those systems.



The USS Santa Fe (SSN 763), a Los Angeles-class fast-attack submarine, transits the Pacific Ocean in March 2025. APL's analysis of magnetic anomaly effects improves understanding of how these environmental factors influence sonar performance on deployed submarines. Credit: U.S. Navy

Magnetic Insights Improve Sonar

While supporting active countermeasures like next-generation jammers, APL is also helping the Navy better understand how naturally occurring electro-magnetic phenomena affect sensor performance. Laboratory experts conducted a case analysis under the Maritime Surveillance Systems Program to examine how magnetic anomalies impact undersea sonar performance — particularly in high-latitude environments where the Earth's magnetic field is more intense. Using actual operational data, the team identified unanticipated magnetic variance that affected sonar system behavior, highlighting the need for more accurate modeling of the undersea magnetic environment.

The study found that both the World Magnetic Model and the Earth Magnetic Anomaly Grid lose precision below sea level, especially at depth. By analyzing and mapping these anomalies in relation to sensor signal processing, the team helped inform improvements in sonar system performance and undersea navigation — reinforcing electromagnetic awareness as a critical element of undersea warfare.

When the Navy issued the requirements for a replacement jammer, there was no industry business case for such a high-power, extreme broadband amplifier, meaning no immediate off-the-shelf solution was available. Leveraging nearly a half century of electronic warfare expertise, APL scientists and engineers, through tasking with the Office of Naval Research, partnered with industry to mature a solid-state amplifier and associated phased array antennas capable of meeting the Navy's challenging requirements.

The high-power amplifier and phased array technology incorporated into NGJ-MB allow Navy Growlers to engage enemy air defenses at increasingly longer standoff ranges, providing increased survivability and mission effectiveness.

Monitoring and Defending the Space Domain

As space grows more congested and contested, national security increasingly depends on the ability to defend the homeland, protect critical space assets, and detect emerging threats in the highest of high grounds. APL is exploring engagement capabilities and advancing technologies that enhance satellite survivability and sensors capable of tracking high-speed objects in orbit. These efforts help ensure U.S. space operations remain resilient, responsive, and informed.

This year, U.S. Space Force's Space Systems Command selected APL to serve as technical direction agent (TDA) for the Space Force's Space-Based Interceptor (SBI) program, in support of Golden Dome for America, an ambitious initiative to explore missile intercept capabilities from orbit that is reshaping the nation's approach to homeland defense and deterrence against advanced aerial threats.

As TDA, APL serves as an independent, conflict-free advisor to ensure system-architecture consistency across industry partners. The SBI program is structured around a prize-based acquisition model — a coordinated approach in which commercial companies invest early and compete for additional funding at designated development milestones. APL will help define and manage the technical interface documents that link the system's segments, ranging from fire-control and ground elements to the constellation of interceptors in space, and ensure a synergistic interface between program participants so that the government can make informed, data-driven decisions.

This effort builds on missile defense expertise that dates back to APL's earliest days. The Lab played a defining role in the development of the first sea-based ballistic missiles and serves as TDA for Ground-Based Midcourse Defense, the only operational system currently protecting the U.S. homeland from long-range ballistic missile attacks.

“From our 80-plus year history with Navy air and missile defense, to our defining innovation of Ballistic Missile Defense from the Sea, to our long history with interceptors, APL's heritage gives us a deep understanding of the technical and operational challenges in this regime,” said Jeff Cooley, who manages APL's Strategic Missile Defense Program Area.

The Lab also worked with U.S. Space Force to design and develop an experimental imaging instrument for an upcoming flight opportunity. Named Agamotto, the instrument relies on event-based sensing technology, where each pixel in the camera operates independently to detect changes in the environment. A leap from traditional cameras, where pixels work simultaneously to capture full images, the technology could revolutionize activities such as space situational awareness.

And finally, in 2025 APL launched a digital engineering program tailored to national security space design and development — a move calculated to accelerate how military and intelligence space systems are designed,

tested, and fielded. The program leverages digital modeling, simulation, and engineering to shorten development timelines, improve system reliability, and reduce risk while maintaining security and responding to operational demands unique to U.S. missions. By building a robust digital backbone, APL aims to enable rapid design changes, thorough virtual testing, and more efficient integration of complex capabilities.

The heart of the effort lies in creating end-to-end, digitally defined system architectures that allow engineers to model entire space systems — from sensors and platform dynamics to signal processing and deployment environments — before manufacturing begins. As part of this broader architecture approach, systems modeling language models can be executed in a digital environment to support rapid-turn analyses for government decision-making. This reduces reliance on incremental prototyping and helps identify flaws or integration issues early, saving time and cost while improving mission assurance. It also accelerates requirements development, interface definition, and other engineering products, enabling design and development at speed and scale through improved communication across the acquisition and operational communities. In national security space, where reliability and responsiveness are critical, these digital tools also facilitate agile adaptation to mission needs.



APL's work in monitoring and defending the space domain helps strengthen space-enabled effects for the Joint Force, including GPS, missile warning, and electromagnetic interference detection. Here, U.S. Space Force Guardians assigned to Space Delta 5 monitor computer workstations on Dec. 18, 2025, at Vandenberg Space Force Base, California, supporting command and control of the Combined Space Operations Center. Credit: U.S. Space Force

Modernizing Fleet Repair Capabilities and Shipboard Operations

APL initiatives to modernize fleet capabilities with cutting-edge manufacturing, robotics, and materials technologies are contributing to a more agile, self-sufficient maritime industrial base — one in which repairs, reconfigurations, and mission-critical production can happen at sea or on short notice. Tailored to shipboard and naval operations, these innovations promise to improve readiness, reduce reliance on extended supply chains, and deliver new levels of flexibility to forces deployed around the globe.

In collaboration with the Johns Hopkins Whiting School of Engineering, APL researchers have created a network for accessing, monitoring, and deploying in-house additive manufacturing and biomanufacturing tools. Dubbed the Agile Manufacturing eXchange (AMX), this innovative capability aims to accelerate the adoption and integration of additive and advanced manufacturing for ship production and repair.

Led by researchers Ahmed Al Bayati and Carly Mayhood, the Hopkins collaborators have developed a network that streamlines supply chains; improves communication between vendors, suppliers, and customers; and lowers the barrier for smaller manufacturers to enter the defense industrial base. AMX is laying the foundation for a secure,

scalable framework that could eventually allow the Navy to access distributed printers — including those operated by small businesses — and rapidly produce mission-critical parts wherever and whenever they're needed.

The exchange is off to a promising start, with the team establishing a connection between an APL facility in Laurel, Maryland, and additive manufacturing machines at the Whiting School in Baltimore. The platform is enabling Johns Hopkins University researchers to access and utilize APL machines seamlessly, securely, and remotely.

“We’re refining and developing a suite of capabilities that allow us to make repairs that are smarter, more precise, and significantly faster,” said Mayhood, a maritime engineer and project manager at APL. “Through our research, we’ll continue to reduce the Navy’s reliance on costly disassembly or replacement parts while keeping ships mission-ready with less downtime.”

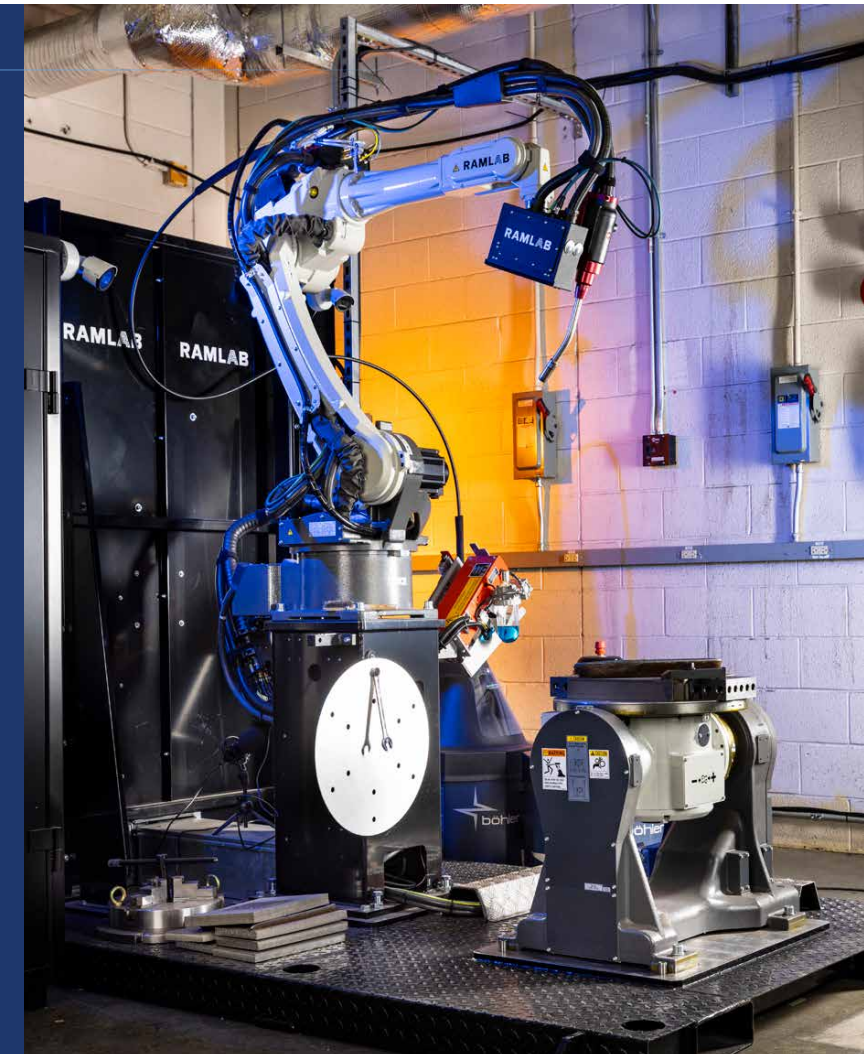
Clinton Bettner, a manufacturing engineer, monitors and adjusts the RAMLAB MaxQ robotic arm as it executes a complex build. By enabling precise, robotic deposition of structural materials, the system accelerates the fabrication of mission-ready components designed to withstand demanding environments.

Armed for Innovation

The newest addition to APL’s advanced manufacturing facility is the RAMLAB MaxQ robotic arm, which the Laboratory is using to study, test, and validate repair and manufacturing approaches — and identify how best to transition these capabilities to industry partners.

Integrated sensing, scanning, and adaptive controls allow the arm to identify issues in large, irregular, or damaged parts while also helping the system develop pathways to make repairs on its own. But humans play a critical part: APL researchers run simulations ahead of builds to ensure the robotic arm does not attempt maneuvers beyond its physical limits, and operators guide processes and finish parts to maintain precision and reliability.

The RAMLAB MaxQ robotic arm, newly added to APL’s Advanced Manufacturing Facilities, expands the Lab’s wire arc additive manufacturing capabilities to produce large-scale, complex metal geometries for a variety of applications.



Meanwhile, APL and the Navy are also addressing the unique challenge of making sure 3D printers can function at sea. Constant motion caused by waves and maneuvering can affect 3D printer performance and the quality of printed parts; to address this issue, the Laboratory developed a novel capability that simulates shipboard motion for additive manufacturing.

Funded by the Naval Sea Systems Command’s Technology Office and developed in partnership with GKN Aerospace, the motion-simulation platform replicates the dynamic environment of a ship at sea, synchronizing motion between the print head and the substrate. The results have been encouraging, with controlled tests producing structurally sound parts under different motion profiles, and the team continues to refine system controls and move closer to producing critical, mission-relevant parts directly aboard ships.

Advancing Undersea Collaboration and Innovation

At the 37th Annual Submarine Technology Symposium — cosponsored by the Commander, Submarine Forces (CSF) and the Naval Submarine League (NSL), and hosted by APL — more than 500 participants from the submarine force, allied partners, industry, academia, and defense communities gathered to explore “Lethality Today and Innovation for Tomorrow.” Keynote remarks from Vice Adm. Robert Gaucher and senior-level Department of War and Navy officials emphasized the importance of uncrewed systems, autonomy, advanced materials, and allied collaboration in strengthening undersea capabilities. APL again played a central role in the program, with Chief Mission Engineering and Integration Officer Christopher R. Watkins cochairing the symposium and APL staff serving as the program chair, the assistant program chair, session chairs, and assistant chairs across multiple technical discussions that advanced shared understanding of future undersea challenges.



An F-35 Lightning II takes flight at Naval Base Ventura County, Point Mugu, California, in September 2025, during Gray Flag 25. APL contributes to exercises like Gray Flag by helping evaluate emerging capabilities and improve tactical integration in joint environments. Credit: U.S. Navy

The exercise brought together senior military and inter-agency participants to evaluate integrated undersea surveillance systems against an evolving threat in a changing ocean environment. The analytic framework included wargame design, performance modeling, scenario design, and post-event assessment. Insights from the wargame are directly informing force posture plans and capability development for national defense stakeholders.

The Laboratory has also been collaborating with U.S. Army North to help the military anticipate, prepare for, and respond to multidomain dangers inside the United States. Early engagement included APL's participation in Army North's yearlong "Future of Homeland Defense" workshop series — a set of 10 sessions that examined emerging threats through 2040 and brought together experts from across U.S. Northern Command (USNORTHCOM) and key stakeholders in homeland defense, such as U.S. Army Training and Doctrine Command and Army Futures Command, along with the broader homeland defense community.

More recently, the partnership has placed emphasis on efforts to improve the resiliency of critical infrastructure for military readiness, with Army North providing essential

operational insight that shapes APL research. In fact, this collaborative effort spawned the development of ARMMOR, a multidomain threat modeling tool that has been integrated with the Army's Mission Assurance Risk Management System to enable real-time risk assessments and asset prioritization.

As the Army streamlines several major headquarters, including Army North, as part of a broader Department of War realignment effort, the Laboratory is poised to continue and expand this partnership.

"Our close relationship with Army North's senior leaders now positions APL to play an even more consequential role as Army North, Army South, and Army Forces Command merge into the new U.S. Army Western Hemisphere Command (USAWHC)," said Becky Zimmerman, senior strategist for the Homeland Defense Mission Area. "With a much broader operating area, USAWHC will need scalable solutions in critical infrastructure protection, counter-uncrewed aerial systems, and artificial intelligence-enabled strategy — areas where APL is already prepared to contribute."

Anticipating Threats and Strengthening Tactical Integration

Understanding how and where U.S. forces might face emerging threats is essential to maintaining operational advantage. As such, APL leads and participates in exercises that examine strategic vulnerabilities and tactical coordination.

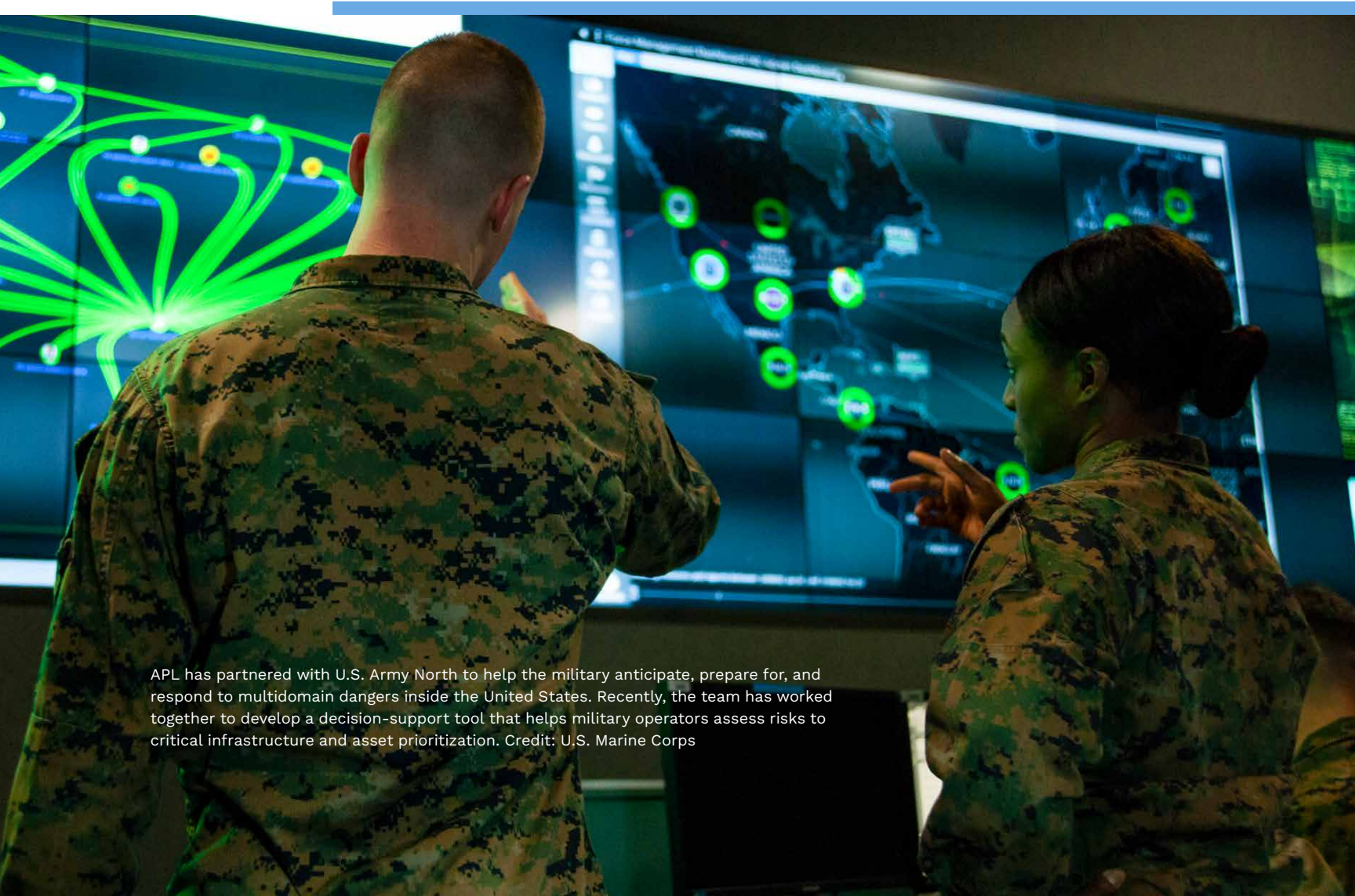
In September, an APL team played a multifaceted role in the annual Gray Flag exercise. Hosted by Naval Test Wing Pacific and Air Test and Evaluation Squadron 9 at Naval Base Ventura County, Point Mugu, the event combines testing and tactics development to evaluate advanced capabilities in a joint and multidomain environment.

The Laboratory contributed expertise across multiple operational areas, including high-altitude balloon experiments for sensing and communications, battle management aids to support faster, more informed decision-making, and rapidly deployable launch platforms to expand tactical flexibility.

APL also analyzed unmanned surface vessel operations, partnered to coordinate and demonstrate remotely controlled hardware across Navy vessels and aircraft, and showcased a rapid prototyping initiative that repurposes commercial- and government-off-the-shelf technologies to meet urgent Navy needs, aimed at increasing speed to fleet.

"By bringing together technical depth, operational context, and rapid execution, APL helped operational teams evaluate emerging capabilities in a complex, joint environment," said Gregg Goyette, APL's Joint Capability Development Program Area manager. "This work demonstrates how the Lab helps bridge strategy and execution and ensures that innovation is not only advanced, but also aligned with real-world operational priorities and decision-making."

And with eyes on emerging threats, APL designed and executed a wargame addressing the advancement of anti-submarine warfare surveillance systems across the Pacific Rim.



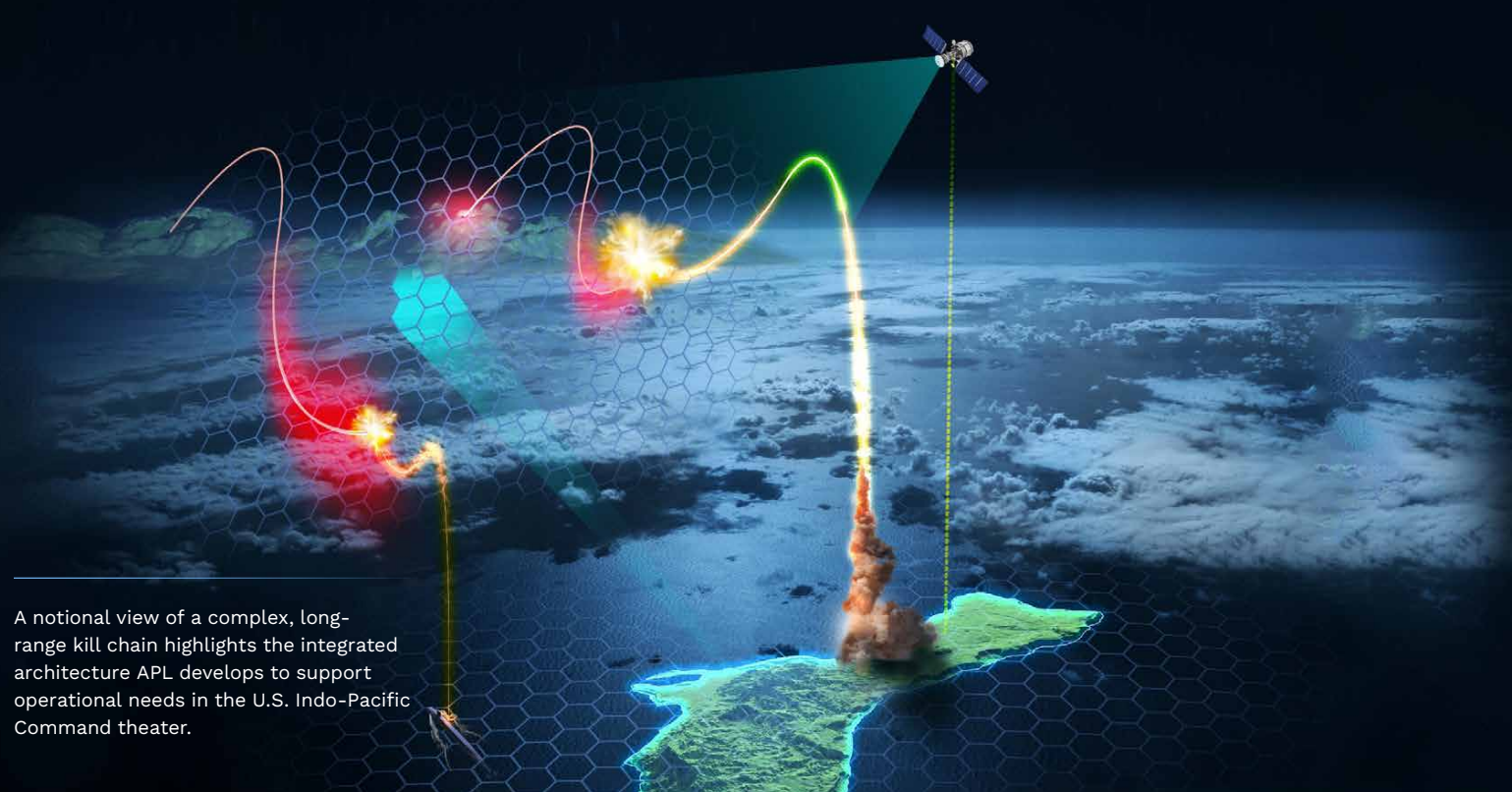
APL has partnered with U.S. Army North to help the military anticipate, prepare for, and respond to multidomain dangers inside the United States. Recently, the team has worked together to develop a decision-support tool that helps military operators assess risks to critical infrastructure and asset prioritization. Credit: U.S. Marine Corps



COUNTERING EVOLVING THREATS

Innovation and technology are reshaping the nature of competition and conflict, blurring the boundaries between physical, digital, and biological threats. APL fuels the nation's ability to stay ahead of these shifts by identifying vulnerabilities and developing solutions that strengthen security, defense, and resilience. From hypersonics and autonomy to biotechnology and infrastructure protection, the Laboratory is integrating science, engineering, and analysis to anticipate and counter tomorrow's threats today.

Evolving threats cross domains, from hypersonic weapons and autonomous systems to cyberattacks and biological hazards. APL integrates sensing, analytics, and mission engineering to help sponsors anticipate risks, strengthen defenses, and improve resilience.



A notional view of a complex, long-range kill chain highlights the integrated architecture APL develops to support operational needs in the U.S. Indo-Pacific Command theater.



A plasma spray torch in operation. This robust, low-cost, versatile method can deposit metallic and ceramic coatings. At APL, researchers are using this technology to advance materials that will operate in extreme environments, such as hypersonic flight.

Demonstrating and Hardening Hypersonics

The United States faces significant technical challenges in developing and fielding effective hypersonic weapon systems, an essential technology in today's contested operating environment and a critical difference-maker in the nation's ability to project power and protect itself and its allies against a new generation of threats.

From basic aerodynamic research to innovative technology development, APL is driving multiple technical improvements that are vital to the effectiveness and survivability of the nation's offensive and defensive hypersonic capabilities. The cutting-edge technologies conceived of and developed by APL are critical to operational concepts supporting national priorities such as the Golden Dome for America missile defense system, operational needs in the U.S. Indo-Pacific Command (INDOPACOM) theater, and ensuring survivable reentry vehicles against increasingly capable adversary defenses. The Laboratory leads projects that advance the state of the art in guidance, navigation, and control of these vehicles; validate the tools used to predict vehicle aerodynamics and aerothermodynamics, including boundary layer transition; and create materials capable of withstanding the extreme thermal environment.

Drawing on the Lab's extensive domain expertise, APL pioneered complex kill chains to engage dynamic targets; is driving the transition of hypersonic boost-glide technology into a successfully flight tested, operationally capable strike weapon system; and is enabling industry development of the world's first operational glide-phase hypersonic

defense capability. Additionally, APL is creating novel high-temperature materials and manufacturing approaches to enable survival of tactical hypersonic weapons, strategic hypersonic payloads, and hypersonic kill vehicles, as well as creating technologies that will ensure the survivability of future strategic reentry payloads. In each application space, APL is a key driver in identifying and mitigating the highest technical risk areas through rigorous design, modeling and simulation, prototyping, and testing. The Lab also matures the effectiveness and reliability of these critical technologies before transitioning them to industry partners to meet sponsor needs.

From hypersonic capabilities for tactical and strategic systems, APL is accelerating the development, implementation, and fielding of these essential technologies.

As examples, in 2025, the Laboratory:

- Developed a kill chain architecture for long-range fires used operationally by the U.S. Navy, Air Force, and Army, combining multiple novel capabilities, which have been exercised in the INDOPACOM theater.
- Delivered Conventional Prompt Strike Mission Planning tools that accelerated the deployment of hypersonic strike capabilities for the U.S. Army and the Navy through the success of an end-to-end flight test of the Army's Rapid Capabilities and Critical Technologies Office's conventional hypersonic missile.

- Created low-cost, high-performance, oxidation-resistant, high-emissivity leading-edge coatings that passed extensive arcjet testing and were successfully flight tested on sounding-rocket experiments in 2025.

- Designed, prototyped, and delivered advanced reentry technologies — including hardware demonstrating thermal protection system advanced materials — as part of investment by the Department of War (DOW) in modernization and recapitalization of the nation's ballistic missile forces.

- Developed and demonstrated an integrated simulation to incorporate countermeasure modalities into a multifunctional payload to demonstrate compelling effectiveness against adversary threat systems and is finalizing requirements for platform integration.

- Identified future capabilities for the Air-Launched Rapid Response Weapon (ARRW) through multi-disciplinary engineering trade studies leveraging APL's deep knowledge of the ARRW system and analytical tools, developing a clear path forward for both production and further development of advanced capabilities for ARRW.

- Predicted end-to-end flight performance of the Hypersonic Attack Cruise Missile and partnered with industry, simultaneously enabling the program to pass through Critical Design Review and reducing risk during critical phases of flight.



U.S. Navy and Japan Maritime Self-Defense Force ships operate together in the Philippine Sea during a large-scale exercise that integrates joint and allied forces across multiple domains. These opportunities enable APL to perform advanced mission planning and technical analysis to help sponsors assess and field capabilities for operating in contested environments, including hypersonic-related missions and defenses. Credit: U.S. Navy

Advancing Autonomous Systems and Countering Drone Threats

As autonomous systems grow more capable and widespread, APL is advancing tools and architectures that can defend against adversarial threats and improve assets warfighters rely on to complete missions across land, sea, and air.



APL is advancing autonomy and sensing that help warfighters detect and mitigate explosive hazards using fielded robotic platforms such as the Man Transportable Robotic System Increment 2, shown here during an explosive ordnance disposal field exercise at Camp Hansen, Okinawa, Japan. Credit: U.S. Marine Corps



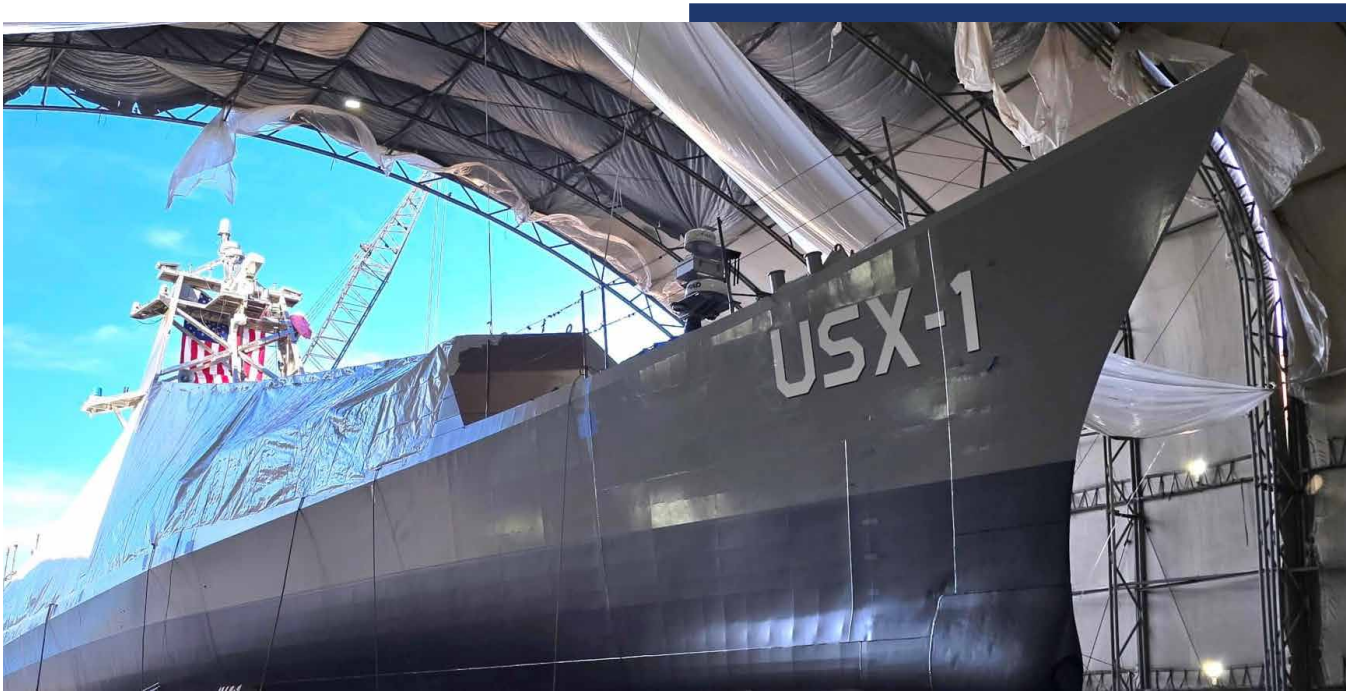
Dead Center is an APL-developed low-SWaP artificial intelligence system that performs real-time onboard target detection on autonomous platforms, sending only concise data to reduce bandwidth and enable fully autonomous intelligence, surveillance, and reconnaissance missions. Marines with 1st Light Armored Reconnaissance Battalion train with Dead Center at Camp Pendleton in August 2025. Credit: U.S. Marines Corps

On the Ground:

APL is collaborating with the U.S. Army and Navy to develop autonomous technologies that clear large areas of unexploded ordnance and other hazards. APL is adapting sensor compute systems developed under prior Office of Naval Research and U.S. Army Ground Vehicle Systems Center efforts for integration with a widely used explosive hazard-mitigation platform known as the Man Transportable Robotic System (MTRS). This effort aims to enable autonomous navigation, standoff detection, and scalable hazard clearance over operational surfaces such as airfields. The team is leveraging proven simultaneous localization and mapping technologies to equip MTRS with robust autonomous navigation capabilities.

In Austere Environments:

Dead Center is a low-SWaP (size, weight, and power) tactical-edge automated target recognition (ATR) and mission-level autonomy solution that enables users to build and deploy custom autonomous missions and manage custom ATR algorithms in austere, disconnected environments. It is one of DOW’s pioneering efforts in low-SWaP tactical-edge autonomy and ATR agility for full-motion video and synthetic aperture radar. APL delivered Dead Center systems to several Marine Corps units for operational use, and systems will be delivered at scale for small unmanned aerial system utilization as part of a Program of Record for the Marine Corps.



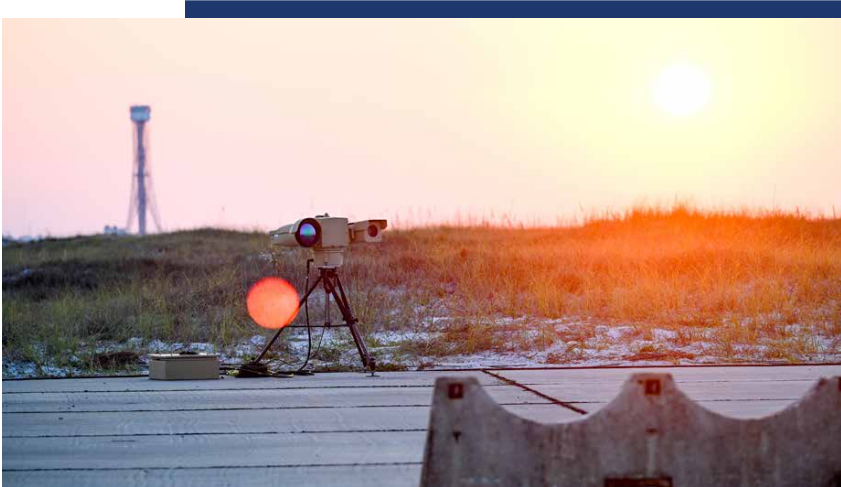
APL led test and evaluation of the experimental vessel USX-1 Defiant’s autonomy software. The ship supports DARPA’s No Manning Required Ship (NOMARS) program and is set to become a first-of-its-kind, fully autonomous, medium-sized vessel capable of extended operations at sea. Credit: DARPA

On the Seas:

APL is integral in ensuring the Defense Advanced Research Projects Agency’s (DARPA) No Manning Required Ship (NOMARS) — set to become a first-of-its-kind, fully autonomous medium-sized ship — will demonstrate extended autonomous operation at sea. For NOMARS to execute long missions at sea without human intervention, the vessel requires novel hardware and software solutions for onboard executive autonomy, machinery configurations, propulsion, and control schemes. The Lab led test and evaluation of the ship’s autonomy software by defining the core autonomy architecture and conducting iterative simulation testing on the autonomy and perception software to validate performance. Early in the program, the Lab also helped define the list of functional requirements, international regulations, and domestic and Navy-recommended certifications that the vessel will meet. The experimental NOMARS vessel — the USX-1 Defiant, designed and built by Serco Inc. — was christened in August 2025 and is scheduled to undergo rigorous and extensive testing ahead of a three-month at-sea demonstration period before a planned transition to the Navy’s Unmanned Maritime Systems Program Office (PMS 406).

In the Skies:

During the Falcon Peak exercise for counter-unmanned aircraft systems (UAS) hosted by U.S. Northern Command (USNORTHCOM) and North American Aerospace Defense Command (NORAD), APL presented a new drone-defense system, called Skyward, designed to protect infrastructure and citizens in the homeland as well as U.S. warfighters and interests worldwide. Skyward is a decision-support tool for defense operators that offers a real-time threat assessment and course-of-action recommendation for each drone it detects. At the exercise, APL seamlessly integrated Skyward with commercially available sensors and USNORTHCOM’s drone sensor fusion solution, the Advanced Tactical Hostile Engagement Awareness (ATHENA) toolkit.



Falcon Peak 25.2 featured tests and demonstrations of counter-UAS systems, including APL’s Skyward decision-support tool and a range of commercial sensors, like the one pictured above. Credit: Department of War



Golden Horde: Networked and Collaborative Autonomy

In 2021, the Air Force Research Laboratory (AFRL) selected APL as the technical lead for the Golden Horde program, a pioneering prototyping effort focused on developing a digital, agile, open, and government-owned research and development testbed capability for networked, collaborative, and autonomous (NCA) weapon technologies.

Over the past four years, APL has collaborated closely with AFRL to provide technical guidance to participating organizations, known as “gladiators,” to develop NCA weapon technologies. These gladiators have competed in a live, virtual, and constructive arena developed by APL and dubbed the “Colosseum,” which gives them the opportunity

to test, evaluate, and develop algorithms for an NCA system in a digital approximation of the real world. The Colosseum has evolved into a versatile space that now simulates a wide range of weapon concepts and scenarios with a recent focus on complex maritime environments. The Colosseum’s utility has been further enhanced by the addition of a tool that simplifies and speeds up analyzing complex data and performing trade studies and by the integration of Colosseum software onto classified systems at both APL and Eglin Air Force Base for in-the-loop evaluations.

The Golden Horde program has successfully demonstrated that a wide range of autonomous systems developed by industry and academia can run on a common software framework and be adapted to surrogate weapon software and hardware, showcasing the program’s potential for scalable innovation. APL continues to work closely with the AFRL Munitions Directorate, the Air Force Life Cycle Management Center, and other stakeholders to inform program direction and identify potential future use cases to expedite the advancement of more robust and effective artificial intelligence for the warfighter.

Participants gathered in APL’s Semmel Center to participate in a Golden Horde competition, part of the Air Force Research Laboratory’s program to test and refine next-generation networked, collaborative, and autonomous weapon system technologies.



Securing Critical Infrastructure and Control Systems

With the nation’s water supply, energy production, banking, agriculture, and other critical civilian and military support systems under constant threat of cyberattack, APL is working to safeguard these systems by developing tools and frameworks that detect, prevent, and mitigate these attacks before they cause harm.

In the national defense arena, Situational Awareness, Boundary Enforcement, and Response (SABER) provides passive, out-of-band network monitoring and alerting, enabling shipboard systems to detect and respond to cyber threats, particularly to hull, mechanical, and electrical enclaves. As the SABER Program Office is expanding SABER’s footprint to fully cover the fleet, they’ve asked

APL, as a technical direction agent, to spearhead the use of SABER in additional enclaves, such as the Navigation and Combat Systems Enclave.

The APL-developed More Situational Awareness for Industrial Control Systems (MOSAICS) is a vendor-agnostic, next-generation cybersecurity framework for industrial control systems. Developed to detect, characterize, and ultimately respond to cyberattacks in real time, MOSAICS was deployed operationally over the past year at key Navy installations in the continental United States and in the INDOPACOM area of responsibility. The framework was adopted as a baseline standard by the Office of the Under Secretary of War for Acquisition and Sustainment and was proposed for inclusion in DOW’s unified facilities criteria.



The Navy-engineered SABER system, developed by APL with government and industry partners, provides frontline cyber defense for surface ships. It autonomously monitors hull, mechanical, and electrical (HM&E), navigation, and combat subsystems, detecting intrusions that threaten mission-critical operations.



“APL cybersecurity tools are designed to integrate across sectors and systems. This ensures that whether they’re working at a municipal water plant or a large industrial facility, operators have reliable options to detect, respond to, and withstand cyber threats.”

— Ray Yuan, APL’s Mission Area Executive for Cyber Operations

The Lab also released a new MOSAICS tool called BAS/CS — short for Behavioral Alerting Sets for Control Systems and pronounced “basics” — that standardizes alerts across diverse industrial control systems, enabling more consistent and rapid threat detection and response. With its common alerts IDs and unified correlation rules, BAS/CS reduces confusion stemming from varied vendor-system alerts and helps operators detect complex attack patterns more efficiently. Already deployed in the same military control-system environments as MOSAICS, the capability

supports infrastructure sectors such as electricity, water, and natural gas — systems increasingly targeted by adversaries.

“Protecting the nation’s critical infrastructure demands a flexible ecosystem of capabilities that can meet the diverse needs of government and industry,” said Ray Yuan, APL’s mission area executive for Cyber Operations. “APL cybersecurity tools are designed to integrate across sectors and systems. This ensures that whether they’re working at a



Representatives from more than 50 public and private sector organizations took part in the Vista Gladiator homeland defense wargame in January at APL. The event was sponsored by the Joint Chiefs of Staff in partnership with NORAD and U.S. Northern Command.



APL participants in Vista Gladiator included (from left) Lauren Ice, Kristine Henry, Liz Parkin, and Collin Timm, who were joined by Brian Hall, deputy foreign policy adviser with NORAD and U.S. Northern Command.

municipal water plant or a large industrial facility, operators have reliable options to detect, respond to, and withstand cyber threats.”

In January, APL hosted Vista Gladiator, a weeklong wargame to examine the dependence of the military on private sector critical infrastructure, as well as the coordination needed among the military, government agencies, and industry partners to secure logistics operations from emerging threats.

Representatives from more than 50 public and private sector organizations took part in the game, outlining ways to prepare for and respond to a range of potential challenges, including adversary threats to infrastructure and supply chains as well as extreme weather events. A main objective was to ensure the agility and survivability of joint force systems, personnel, and operations, focusing on such capabilities as supply, maintenance, deployment and distribution, engineering, and contracting.

APL expertise was integral to enhancing the technical, scientific, and operational realism of the game and included the Lab’s insights on the national security aspects of transportation, food and agriculture, all-hazards and climatological effects, and counter-information operations.

“Homeland defense has become even more critical as the threats have come to our shores in recent years,” said Liz Parkin, manager of the Resilient Critical Infrastructure program in APL’s Homeland Defense Mission Area. “APL can help frame critical challenges from many angles and through the eyes of many military and government sponsors, in ways they may not be able to see from within their own organizations.”

Vista Gladiator successfully called attention to gaps in authorities, priorities, technology, and funding among partners, and it revealed actions for improving national coordination across public and private sectors.

“This exercise allows us to practice, explore lines of authority, and get problems in front of the right people,” said Air Force Maj. Gen. Constance Jenkins, who heads the Logistics and Engineering Directorate for NORAD-NORTHCOM. “I like to call Vista Gladiator an exercise in ‘contested logistics’; we must be able to defend the nation’s and continent’s critical infrastructure, move commodities, and respond to threats in the homeland.”

Integrating Biology and Technology for Defense

APL is combining scientific insight with technological innovation to strengthen readiness and response in complex operational environments. Through military exercises and applied research, Laboratory experts are helping defense and public health leaders prepare for biological hazards, improve medical decision-making, enhance safety in the field, deliver tangible support to warfighters, and determine technical solutions to optimize detection, prevention, and response.

The Lab led planning and facilitation of Mālama Pacific, the first U.S. Army Pacific (USARPAC) biological defense tabletop exercise, signaling this as an increasing area of concern. Sponsored by the U.S. Army Nuclear and Countering Weapons of Mass Destruction Agency, the exercise focused on ensuring U.S. forces in the western Pacific could operate if confronted with biological threats — from naturally occurring disease outbreaks to human-made bioweapon deployment.

Drawing on knowledge of USARPAC's mission and operations and relevant geography, APL served as exercise technical adviser and facilitator, presenting complex, challenging, and in-depth scenarios that challenged the Army and its partners to respond to a variety of biological incidents across multiple phases of conflict.

“Partnering with USARPAC gives our scientists and engineers the opportunity to deliver real solutions to real problems,” said Jeff Bacon, a senior scientist at APL who led the exercise facilitation team. “Exercises like Mālama Pacific allow APL to connect warfighters with cutting-edge research and technology, ensuring our nation can fight and win when faced with any biological incident.”



Participants gather for Mālama Pacific 2025, a U.S. Army Pacific biological defense tabletop exercise planned and facilitated by APL that examined how forces could operate while responding to biological incidents across multiple phases of conflict. Credit: U.S. Army



Participants prepare for Special Operations Forces Arctic Medics 2025, an exercise to strengthen readiness for medical and biodefense challenges in extreme cold-weather environments. At the symposium, APL shared insights aimed at protecting forces against various biological pathogens and chemical threats associated with Arctic operations. Credit: U.S. Coast Guard

Bacon also participated in an APL-led symposium in Alaska to help DOW prepare for chemical and biological threats in extreme cold weather. Held near Fort Wainwright and the University of Alaska Fairbanks, the symposium included stakeholders from NORAD, USNORTHCOM, and Special Operations Command North, as well as allies from Canada and the United Kingdom, and laid the groundwork for the Special Operations Forces Arctic Medics 2025 exercise.

Providing critical training and support, APL equipped attendees to identify and protect themselves against various biological pathogens and chemical threats associated with Arctic operations. Among the symposium's comprehensive range of topics were natural, accidental, and deliberate biological threats, with particular focus on reemergent pathogens stemming from reductions in permafrost and ice sheeting in the Arctic region. The training included familiarization with field-forward diagnostics and detection approaches to bolster biodefense and below-zero medicine by providing actionable pathogen data in harsh, resource-limited environments. Participants shared awareness, best practices, and lessons learned in chemical and biological defense technologies and activities, strengthening regional cooperation, preparedness, and integrated deterrence.

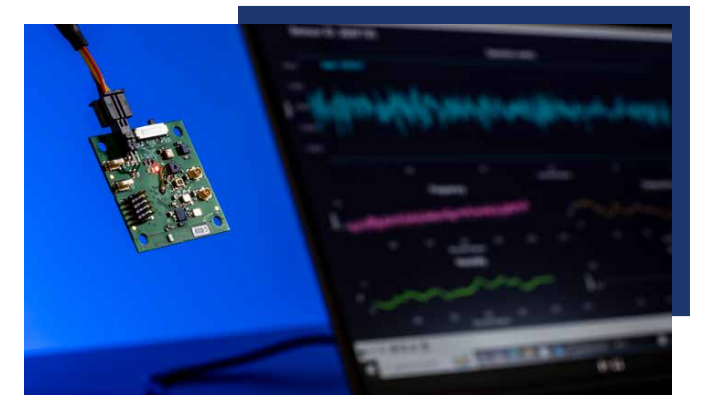
An APL staff member works in a biosafety laboratory, one of several specialized facilities that enable staff to safely help the U.S. anticipate, counter, and prevail against biological threats.

Countering Chemical, Biological, Radiological, Nuclear, and Explosive Threats

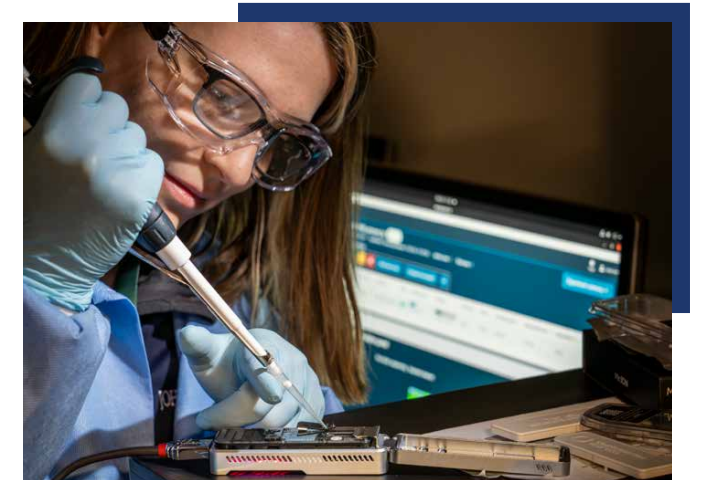
APL is tapping innovations in sensing, analytics, and autonomous systems to help the nation anticipate, detect, and counter chemical, biological, radiological, nuclear, and explosive (CBRNE) threats — and give decision-makers faster, more accurate insight into complex hazards and response options.

As part of the DARPA-sponsored SIGMA+ program, APL assessed an early warning system for biothreats or disease outbreaks that uses wearable physiological sensors. Using advanced epidemiological modeling and analysis, researchers showed that wearable-based sensor networks that collect timely data from as little as 5% of a city's population could identify the onset of an influenza season up to two weeks earlier than traditional public health surveillance and could also provide earlier notice of a large-scale, intentional anthrax attack. Earlier detection and geolocation of exposed individuals could dramatically improve the speed and effectiveness of response efforts.

Following the same strategy, APL researchers are developing tools that enable warfighters and forward-deployed investigators to analyze biological materials directly in the field. The Lab's machine learning for metagenomics pipeline helps identify and assess microorganisms in collected samples. The system analyzes genetic data to classify potential threats into five risk categories, using statistical and machine learning models to detect even previously unseen organisms. Tested with real and simulated data, the tool achieved 95% accuracy in identifying threat clusters and is being prepared for field deployment, where it will give investigators near-real-time assessments to guide response decisions and enhance warfighter safety and situational awareness in biologically contested environments.



A miniaturized airborne sensor supports rapid detection and assessment of biological and chemical aerosols, strengthening APL's work to counter CBRNE threats and inform timely operational response.



APL staff integrate laboratory-derived biological data with advanced artificial intelligence foundation models to uncover novel insights and improve predictive capabilities for biological research and defense applications.

ACCELERATING PROGRESS THROUGH PARTNERSHIPS

Today's national security challenges demand rapid innovation, a call APL is answering by actively engaging commercial partners from across industries to identify and leverage their capabilities, manufacturing capacity, and cutting-edge research — while remaining an independent, trusted partner to the government. By combining its deep technical expertise and mission understanding with industry's ability to rapidly scale emerging capabilities, APL helps bridge the gap between early-stage research and operationally relevant solutions.

These partnerships also foster an ecosystem in which government, academia, and industry team up on technologies that address the nation's most pressing challenges. In 2025 alone, APL demonstrated more than 285 capabilities while working to ensure that innovations were transitioned efficiently — often guiding prototypes through testing, evaluation, and refinement in close coordination with commercial collaborators to meet mission needs.

Here are a few highlights from 2025:

Intuitive Machines and APL are building an integrated space-to-ground network to support NASA's and the nation's communications and positioning, navigation, and timing objectives for civil, security, and commercial space. Leveraging the Lab's advanced networking technology and Intuitive Machines' optimization of data routing and security for the resilient lunar communications backbone, this technology and partnership benefit long-term lunar and cislunar operations.

APL and **Microsoft** demonstrated an artificial intelligence (AI) agent that uses cloud-hosted large language models to coordinate heterogeneous robotic teams. Microsoft's scalable compute and centralized processing capabilities are providing the capacity for complex multirobot reasoning and synchronized tasking across robotic systems.

As APL taps into AI to enable the real-time use of synthetic aperture radar aboard small, lightweight autonomous platforms, the Lab is leveraging an **NVIDIA** full-stack developer platform to develop faster and higher-resolution imagery, particularly for rescue and intelligence-gathering users.

APL and **Nanoionix LLC** are advancing two synergistic efforts to rapidly mature and transition radiatively cooled ceramic coatings for high-temperature applications, including infrared windows and radomes. These game-changing partnerships unite government, academia, and industry to accelerate operational testing and commercialization of next-generation materials.

NASA's Polylingual Experimental Terminal (PEXT) demonstration showcased a first-of-its-kind wideband communication system that enables satellites to operate across government and commercial networks, advancing a next-generation space communications infrastructure ahead of NASA's shift to commercially sourced services. APL's work on PEXT is leading to more flexible, high-data-rate connectivity standards and positions this technology for broader adoption. The Lab is actively engaged with industry to commercialize this technology for broader use, following an approach similar to that used for commercializing APL's Frontier Radio with Rocket Lab in recent years.

APL worked with **Raytheon** to integrate a new electromagnetic warfare capability into the Navy Zumwalt combat system and demonstrate operational utility within 18 months — an effort capped by the system's 2025 deployment on USS Michael Monsoor. This extensible capability has been adapted and evaluated for deployment with other Navy ship combat systems, including Aegis and the Ship Self-Defense System, and unmanned surface vessels.

APL's update to the Modular Payload design standard has enabled industry partners such as **Shield AI** and **AeroVironment, Inc.** to quickly integrate and test sensors and electronic warfare systems on unmanned platforms. This effort has streamlined payload integration and provided a clear technical framework that facilitates collaboration with other vendors and accelerates development and operational validation of autonomy and GPS-denied solutions in realistic environments.



BOLD INNOVATION

APL is redefining how artificial intelligence (AI), materials, manufacturing, and biology accelerate innovation for national defense and beyond. Through forward-leaning research, Laboratory researchers are exploring bold new concepts that may not reach the field immediately but are critical in shaping what comes next. By laying the groundwork for more resilient systems, faster innovation cycles, and transformative capabilities, APL is advancing the most innovative and effective technologies into real-world application and strengthening the nation's technological advantage.

APL's GenWar Lab leverages advanced AI and large language model capabilities to support the wargames and tabletop exercises that enable military decision-makers to explore dynamic and wide-ranging mission scenarios.



“GenWar Lab reflects APL’s commitment to combine tools, infrastructure, and talent to leverage AI to find innovative solutions to the nation’s toughest security challenges.”

— James N. Miller Jr., APL’s Assistant Director for Policy and Analysis

Applying AI to Strategic Analysis and Mission Planning

AI is reshaping how the nation approaches analysis, planning, and decision-making. In this domain, generative AI, in particular, opens up new possibilities for modeling complex scenarios and exploring strategies at a pace and scale once decidedly out of reach. This is especially true in wargames and related simulation exercises that national security and military decision-makers use to explore dynamic and wide-ranging mission situations.

In 2025, APL fused its deep analytic and AI capabilities to launch GenWar Lab, an incubator that taps advanced AI and large language model capabilities to support wargames and tabletop exercises.

“This initiative radically accelerates APL’s ability to harness the power of AI and advanced analytics to augment traditional wargaming methods,” said James N. Miller Jr., APL’s assistant director for policy and analysis. “GenWar Lab reflects APL’s commitment to combine tools, infrastructure, and talent to leverage AI to find innovative solutions to the nation’s toughest security challenges.”

Three distinct capabilities have already emerged out of GenWar Lab: GenWar TTX, GenWar Sim, and GenWar X.



A conceptual demonstration of APL’s generative wargaming capability. The Blue Team uses natural-language prompts to request strategic recommendations and give orders to meet a mission objective. Outcomes are then adjudicated through modeling and simulation and presented in a chat-based interface and digital map. The graphic above is notional and all depicted locations are fictional.

GenWar TTX:

Brings AI Into the Game —

GenWar TTX is a digital environment where senior military commanders and civilian leaders can engage in tabletop exercises that are enabled by a diverse set of AI agents serving as both advisers and adversaries. The TTX platform accelerates and expands wargaming capabilities to enable innovative intelligence analysis and the exploration of AI agent behavior in complex scenarios.



GenWar Sim:

Accelerated Modeling and Simulation Wargaming —

GenWar Sim bridges the gap between wargaming and physics-based modeling and simulation, combining human judgment with machine speed. Built on the Advanced Framework for Simulation, Integration, and Modeling (AFSIM), GenWar Sim brings greater rigor and repeatability to every game and analytical excursion by connecting with modeling and simulation to give decision-makers direct access to engineering-driven insights provided by APL.



GenWar X:

Efforts at the Edge —

Building on its flagship capabilities, GenWar Lab is poised to evolve further with a program known as GenWar X, an experimental cell for developing advanced concepts that cut across existing tools and creating new tools in support of the Lab’s AI vision. Designers infuse games with alternative future scenarios and create adversary personas to model how conflicts might play out based on their decisions.





Microsoft and APL teams observe a September demonstration of collaborative robotics enabled by an agentic AI planner that uses large language models to coordinate diverse robotic platforms, showcasing how autonomy expertise and scalable cloud technologies can help move AI from concept to operational use.

Improving Autonomy and Discovery

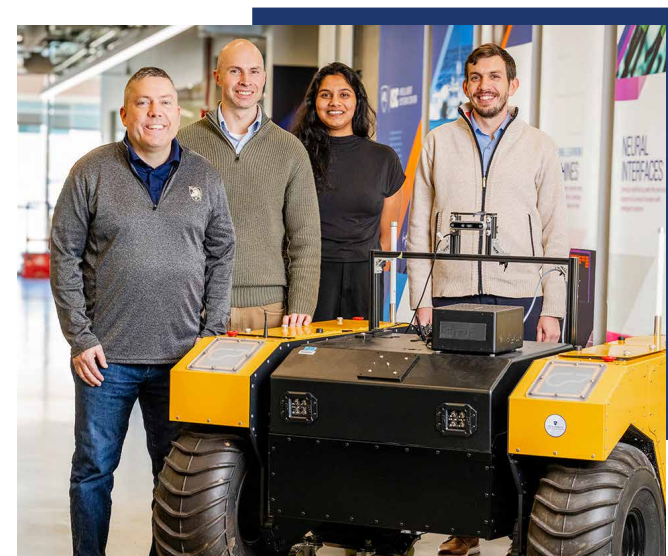
While generative AI enhances how humans think through challenges, agentic AI advances how intelligent systems act within those situations. This next phase of AI development focuses on autonomy — systems that can perceive, reason, and plan in dynamic, real-world contexts. APL researchers are attacking challenges in perception, reasoning, and planning to coordinate teams of diverse robotic platforms, enable autonomous agents to interpret and respond to their surroundings, and extend AI into the lab to fuel scientific experimentation and discovery.

In addition to robust internal and sponsored research, APL has collaborated with a variety of industries to accelerate cutting-edge research and development for the nation. In 2025, APL teamed with Microsoft to demonstrate an agentic AI planner for coordinating heterogeneous robotic teams. The project addresses the tough task of integrating highly specialized individual ground, aerial, and maritime platforms into one cohesive team.

The project's AI agent — called MAESTRO (Microsoft and APL's Ecosystem for Strategic Teaming in Robotics Operations) — interprets and scales human instructions and translates them into coordinated actions. During a September demonstration, David Patrone, a senior intelligent systems leader at APL, issued increasingly complex natural-language commands. Tasks ranged from simply “move forward” to multistep objectives such as “search this area and find a cold bag,” requiring MAESTRO to select the right sensor-equipped robot, plan a route, and validate the result.

APL has since integrated aerial and ground platforms to showcase greater operational range. This effort could enhance missions spanning disaster response to logistics to defense — or any scenario where operators need robots to work together with minimal human intervention.

APL is also looking to solve another difficult autonomy challenge: helping autonomous agents navigate unstructured environments and plan like humans.



Members of APL's Full Scene Extraction team — (from left) Chris Korpela, Corban Rivera, Rohita Mocharla, and Henry Phalen — are developing perception and reasoning models to help robots interpret complex environments and carry out plain-language tasks.

Fresh out of the box, today's robots require extensive training and human guidance — usually with a controller — to complete simple tasks. Under a project known as Full Scene Extraction, however, APL researchers are developing robotic agents that use perception and reasoning models to process complex environments and execute plain-language commands at the same time. By combining advances in large and visual language models, the researchers aim to help autonomous systems not only see and understand their surroundings, but also adapt dynamically and make informed decisions in real time. In situations where a robot once needed several weeks in a simulated environment to learn and complete a task, it can now accomplish that task on its first try.

“The Full Scene Extraction framework directs a robot to reason, on its own, through every step of a task,” said Rohita Mocharla, an APL computer vision engineer. “Where we once had to program each step for a robot to be successful, agentic AI allows the robot itself to plan out these steps.”

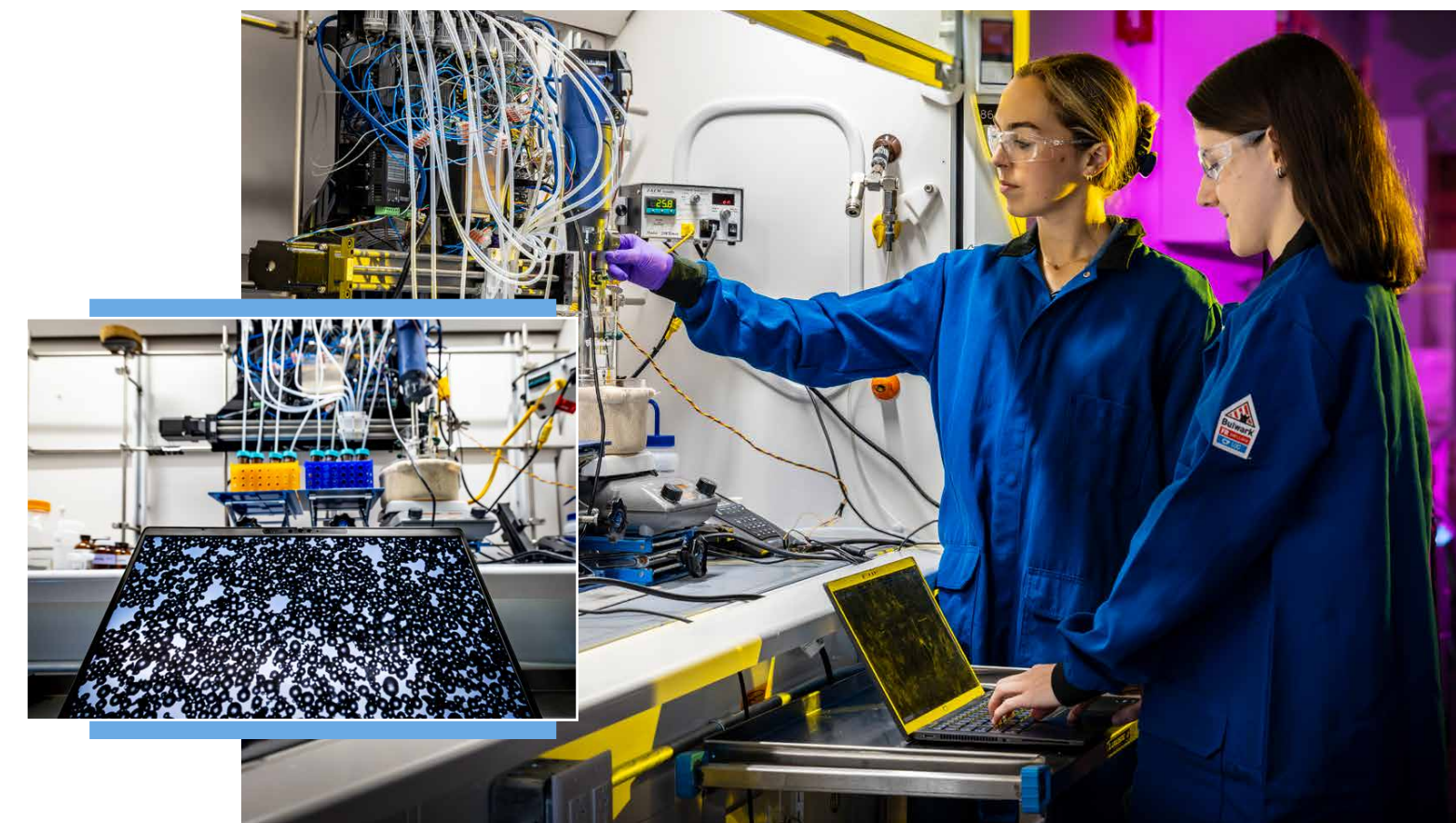
Beyond enabling autonomy in the field, agentic AI is driving innovation in the lab. APL's researchers are leveraging the same principles — automated decision-making, iterative learning, and goal-oriented behavior — to transform how scientific experiments are conducted.

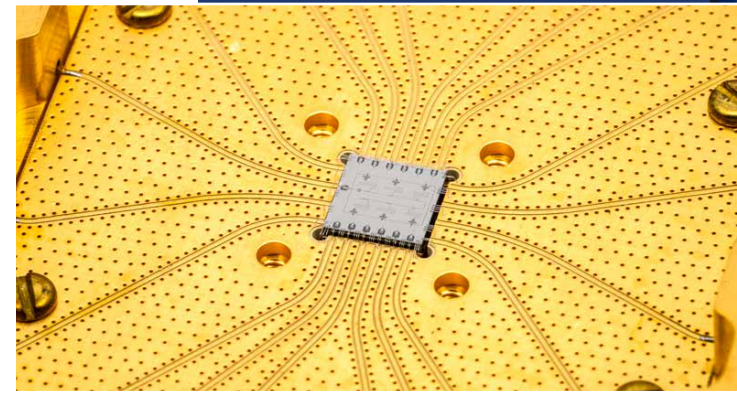
APL created an AI-driven research pipeline that dramatically accelerates experimental process optimization through continual learning. Designed to test, learn, and optimize in a closed loop, the system supports research on microcapsules — tiny particles containing an active substance inside a shell coating that controls its release over time. Given the acronym ATLAS, short for AI-driven, Testing, Learning, and Accelerated Synthesis, the platform has decreased manual experiment time by more than 80% and shows promise for expediting process optimization across a wide range of synthesis problems.

“Using AI as a coinvestigator allows researchers to attend meetings, brainstorm with others, and multitask while their experiment is running,” said Allison Moyer, a materials research chemist and ATLAS team lead.

In August, the team demonstrated how ATLAS can run calculations, search literature, generate a procedure, and execute an experiment, producing an almost on-target microcapsule and decreasing manual experiment time from 9 hours to less than 90 minutes.

Allison Moyer (left) and Jenelle Millison (right) colead ATLAS, an AI-driven platform that dramatically reduces experiment time through automation and continual learning. The platform supports research on microcapsules — tiny particles engineered to release active substances over time — by accelerating process optimization through closed-loop testing, learning, and synthesis.





Exploring Quantum Approaches for Sensing and Computing

As national security missions grow in complexity, quantum technologies are demonstrating the potential to deliver mission-critical capabilities. Quantum computing promises to solve optimization and modeling problems that exceed classical limits, while quantum sensing offers unprecedented precision for detecting and characterizing physical phenomena. APL is advancing both — developing the theoretical, algorithmic, and hardware insights needed to translate abstract quantum science into real operational advantage.

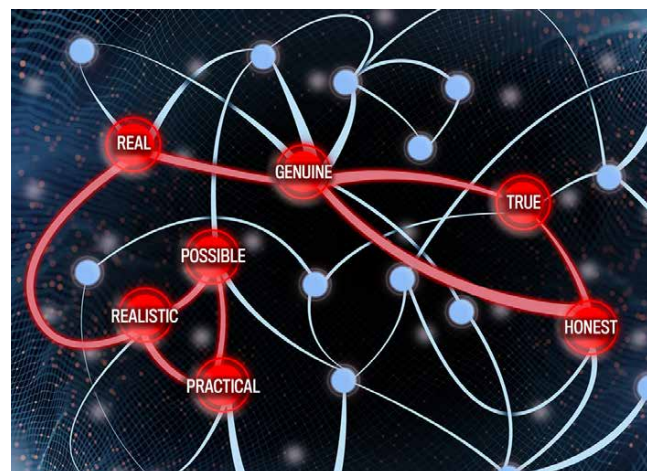
Through the Quantum Benchmarking Initiative (QBI) program, the Laboratory is working with the Defense Advanced Research Projects Agency (DARPA) to identify and assess unconventional approaches to building practical quantum computers. DARPA tapped APL at the start of the QBI program to leverage APL's deep systems engineering expertise and distinguished quantum information team — qualities that uniquely position APL to create frameworks for evaluating quantum computing platforms. This effort enables DARPA to establish engineering benchmarks for what a utility-scale quantum computer should deliver — not just in theory, but in operational ways that matter for specific applications.

This year, APL also demonstrated how a so-called quantum “random walk” algorithm could accelerate semantic text analysis, enabling analysts to identify emerging narratives in large volumes of open-source information faster than classical computing methods allow.



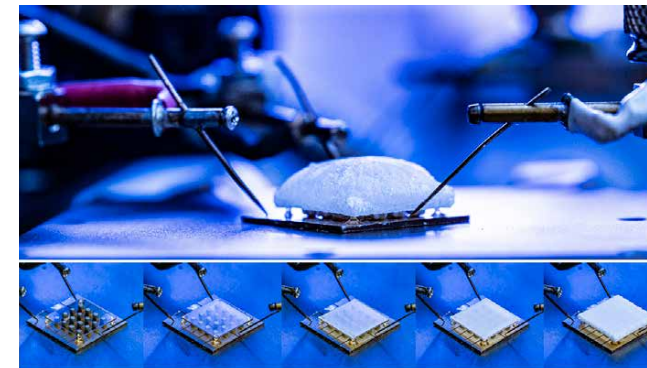
Cryogenic instrumentation supports quantum research by enabling experiments at extremely low temperatures, conditions often required for quantum computing and sensing approaches.

APL teams also applied their expertise in modeling and simulation to study the potential value of quantum magnetometers to the Navy. These devices can detect minute changes in magnetic fields, providing valuable information for naval operators. The study results ruled out certain applications while identifying others that help address maritime challenges.



APL researchers demonstrated that a quantum algorithm can accelerate semantic text similarity analysis, helping analysts identify and track emerging narratives in large volumes of open-source information.

Accelerating Discovery Through Advanced Materials and Manufacturing



A close-up of testing and ice buildup on a CHES-based thermoelectric device. The testing is used to evaluate how efficiently the materials convert electricity into cooling, supporting future solid-state refrigeration and energy-harvesting technologies.

APL researchers are reimagining the development and production of advanced materials to strengthen national security and industrial resilience by combining AI, robotics, and novel fabrication methods to accelerate the design and optimization of high-performance materials.

One class of materials under development at APL could reshape how cooling and thermal management are achieved across defense, industrial, and consumer refrigeration systems. Unlike traditional refrigeration, which relies on compressors and circulating chemical refrigerants, semiconductor thermoelectric — or heat pumping — systems move heat using electrical current, enabling compact, solid-state designs with no moving parts. This is a critical advantage in mission environments where space, durability, and energy efficiency are at a premium.

In a study published in *Nature Communications*, a team of APL researchers and refrigeration engineers from Samsung Research demonstrated how particular high-performance nano-engineered thermoelectric materials invented at APL — known as controlled hierarchically engineered superlattice structures (CHES) — nearly doubled heat-pumping performance at the material level and delivered up to 70% greater performance than currently available bulk thermoelectric devices in a fully integrated refrigeration system.

Beyond improving efficiency, the CHES thin-film technology requires extremely small amounts of active material, addressing potential supply chain constraints, in order to meet the cooling needs of household and industrial refrigeration. The CHES refrigeration module

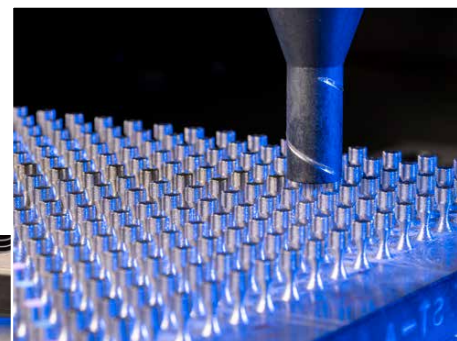
was created by using standard microelectronic semiconductor tools, making it well suited for cost-effective, large-scale adoption.

In recognition of its transformative potential, this technology was honored with a 2025 R&D 100 Award, underscoring its promise to enable next-generation thermal management of both defense and commercial applications.

Separately, APL's Transforming Evaluation and Testing via Robotics and Acceleration (TETRA) project reimagines how mission-critical metallic materials are developed for the defense industrial base. By integrating robotics, additive and advanced manufacturing, automated testing, and AI-guided analysis, the effort is a first-of-its-kind tool that enables researchers to explore hundreds of alloy compositions and processing variants simultaneously, rather than one at a time.

“When developing materials for defense needs, it's not just about the composition of the alloy or system — it's also about how you shape, treat, and refine it,” said Morgan Trexler, who leads the Research Program Area in APL's Research and Exploratory Development Mission Area. “Because we can now explore hundreds of material and process combinations in parallel, TETRA compresses

APL's TETRA program uses blown-powder directed energy deposition to print dense metallic structures and rapidly generate many alloy variants for accelerated testing and evaluation.





Software engineer David Lengel examines printed circuit board (PCB) imagery for import into PCB DR for design recovery. PCB DR allows both automatic and manual reconstruction of the PCB's connectivity and bill of materials. PCB DR's automation and manual workflow allow design recovery of PCBs in days — work that once took weeks — and enables faster reverse engineering and analysis of legacy systems.

A Reverse Engineering Tool for Printed Circuit Boards

PCB DR (Printed Circuit Board Design Recovery) is APL-developed software that accelerates the recovery of PCB designs from X-ray computed tomography (CT) and 3D visible-spectrum imaging. X-ray imagery allows recovery of internal connectivity not visible to the naked eye; 3D visible-spectrum imagery allows automated detection and placement of components on the surface of the PCB. These algorithms, together with an intuitive toolset for manual annotation and recovery, empower users to recover designs in days instead of weeks. PCB DR features a robust, documented application programming interface (API), allowing recovered designs to be exported to external tools, including standard Electronic Computer Aided Design (ECAD) tools.

PCB DR is actively used by many government agencies and partner organizations. In a productivity test by the National Air and Space Intelligence Center, PCB DR cut the reverse engineering time from 24 hours to just 4 hours — a sixfold speedup. The Office of Naval Intelligence reported that PCB DR reduced the time needed to rebuild schematics from weeks down to a few days during foreign matériel analysis. PCB DR's versatility has led to an ever-expanding application space ranging from defense and aerospace reverse engineering to commercial electronics and prototypes.

months of materials discovery into days — and gives us entirely new ways to diagnose problems in legacy systems. It's not just a step forward, it's a leap.”

TETRA leverages several advanced manufacturing techniques, including an additive manufacturing process called blown-powder directed energy deposition, a method where a laser melts metal powder as it's fed into the build area, enables forming of dense structures layer by layer. The technique allows researchers to vary chemical compositions within each sample, enabling hundreds of alloy specimens to be printed on a single plate and prepared for automated testing. In addition to fabrication via additive manufacturing, the lab will feature a state-of-the-art melting furnace for ultrafast synthesis of custom castings from raw material, custom heat treatment furnaces and hot forging equipment for shaping material and modifying its microstructure, and robotic mechanical property measurement.

APL is also teaming up with the Johns Hopkins Whiting School of Engineering to improve how high-performance titanium parts are made using additive manufacturing. By using AI to expand the range of successful manufacturing conditions, the team is speeding up production and making parts that are stronger and more durable. The research was published in Additive Manufacturing in January, and could result in faster, more reliable manufacturing for mission-critical systems.

Building on the Laboratory's extensive experience developing materials for extreme environments, another team discovered a way to apply a specialized coating to intricate internal surfaces. APL researchers adapted a Pulse Combustion Engine (PCE) system that was originally developed by ThermoChem Recovery International to survive extreme heat and acidic conditions. In this effort, the team is using a compact plasma spray torch to coat the interior of the engine with a coating of nickel-chromium-aluminum-yttrium. The protective coating endured over 13 hours of continuous operation, demonstrating its potential to significantly extend the operational life of components that are routinely exposed to extreme heat and acidic conditions.



Leveraging Biomanufacturing to Sustain and Protect

APL researchers are applying biological principles to develop sustainable solutions that meet critical mission needs in remote and resource-limited environments. By engineering biological systems to produce essential materials and medicines on demand, these efforts aim to reduce the burden on the supply chain and strengthen operational resilience.

By examining different feedstocks and growth conditions, APL scientists are developing methods that could enable on-demand food production for military and humanitarian

missions alike — enhancing sustainability and resilience for operations in austere environments where access to fresh provisions is limited and logistics are complex.

Under the DARPA-funded Feedstocks for Food Production effort, which supports the Cornucopia program, the Laboratory is accelerating biomanufacturing to quickly produce safe and reliable sources of nutrition in areas where resources are scarce. The team is studying how algae and other microbes can convert nonpotable water — including pond and gray wastewater — into edible microbial biomass.





“What if we had a way to make food quickly and with whatever water is available? That’s the type of technology we’re progressing toward.”

— Collin Timm, APL’s Chief Scientist for the Physical and Life Systems Branch

“Think about how long it takes to grow grain to produce wheat,” said Collin Timm, chief scientist for APL’s Physical and Life Systems Branch. “It takes time to plant the material, let it grow, harvest it, process it, and then make it into something consumable. But what if we had a way to make food quickly and with whatever water is available? That’s the type of technology we’re progressing toward.”

Another APL team is tackling a serious national security vulnerability — the United States’ dependence on foreign sources for essential pharmaceuticals. A 2023 Department of War report found that nearly 75% of nearly 13,000 small-molecule drugs have their key ingredient manufactured internationally, while 27% rely on supply chains tied to China or have unknown origins. Disruptions in or denial of access to these pipelines could threaten the nation’s ability to produce life-saving medicines when they are needed most.

APL researchers designed and built a system that could transform how active pharmaceutical ingredients are refined and manufactured within the United States. The system streamlines the complex process of separating drug compounds from mixtures — a step normally slowed by batch-type chromatography, which involves flowing chemical solutions through gel- or resin-filled columns. When combined with emerging biotechnologies that enable bacteria to produce pharmaceuticals — and further refined to prevent cross-contamination between molecule-binding solvents — APL’s approach could eliminate this bottleneck and help onshore critical drug manufacturing.

In a separate effort to also reduce dependence on external supply chains, APL funded a small research team to quickly test whether red-blood-cell-like products could be made without relying on donated blood. The team explored the feasibility of producing erythrocyte-like cells that can be freeze-dried and stored long term. This work



(From left) James Johnson, Mallory Solazzo, and Micah Nissly stand with a continuous pharmaceutical manufacturing device developed through a strategic internal investment that focused on maturing promising concepts into prototype-ready, high-impact capabilities.

could have major implications for trauma care in remote or resource-limited settings — especially for warfighters — by enabling safe blood transfusions anytime, anywhere, and with minimal logistical support.

In 2025, APL researchers demonstrated that induced pluripotent stem cells can be reliably grown and directed to become reticulocytes, a precursor of red blood cells. This means functional lab-made red blood cells could be produced from a renewable source without relying on donors. They also developed new preservation methods that could lead to freeze-dried, shelf-stable blood, overcoming the current 42-day storage limit, and designed a prototype bioreactor to demonstrate how the process could be scaled up. The Lab will continue to work with the Office of Naval Research to fabricate, test, and characterize the bioreactor.

Gaining Insight Into Warfighter Health and Injury

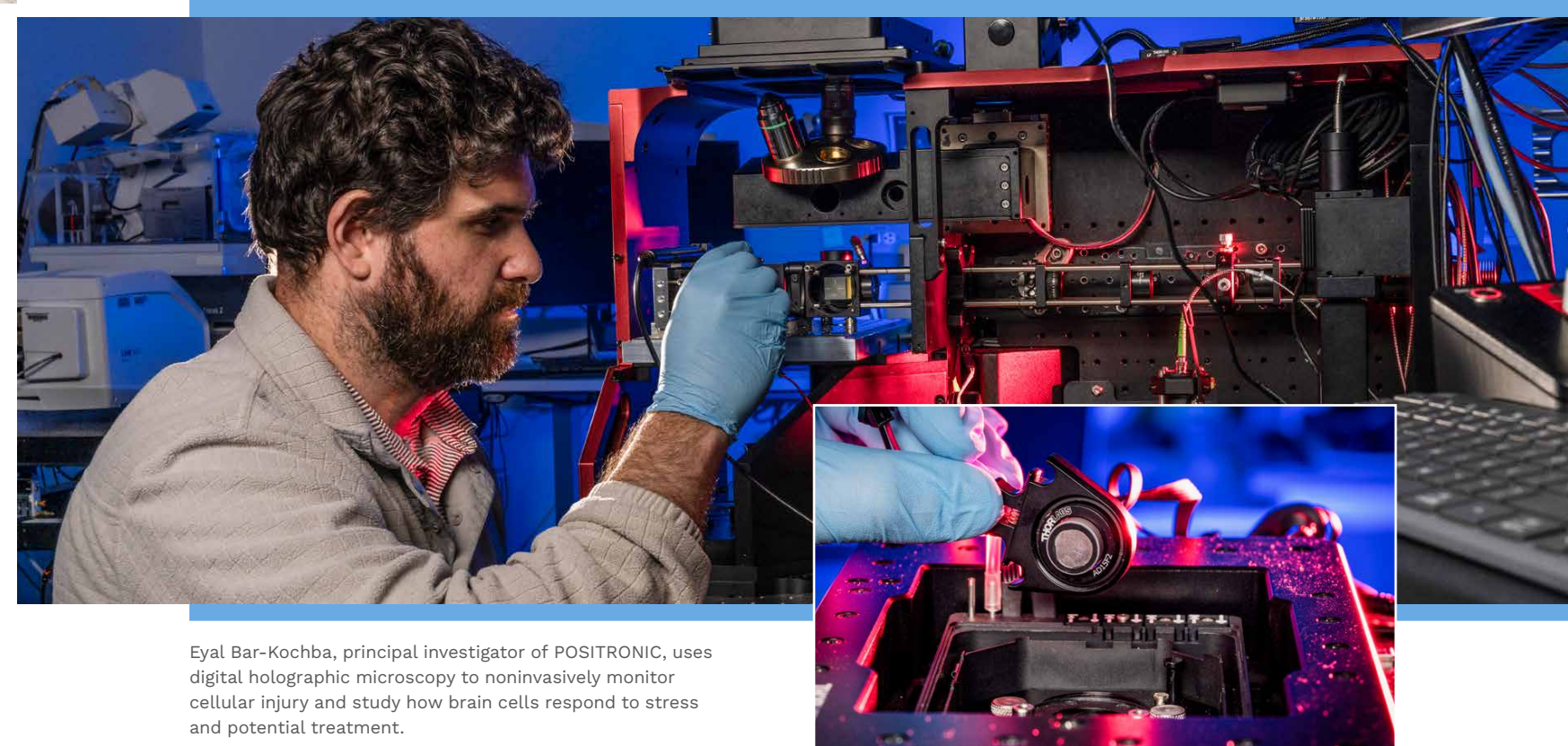
Providers are required to assess warfighter health and deployability at every medical encounter, yet they often lack the critical information needed to accurately evaluate health history and service- and location-specific operational requirements. APL is working with the Department of War to modernize how medical determinations are made by developing a data infrastructure and analytics platform, known as PARATUS, that uses AI and advanced algorithms to enable medical providers to make more accurate, consistent determinations of whether a military member is employable, deployable, and fit for duty or requires medical intervention. By combining quantitative health indicators, advanced analytics, and human performance data, the project aims to identify risks earlier, improve deployment and return-to-duty decisions, and support a unified standard for joint readiness across the armed forces.

Beyond readiness evaluations, APL researchers are advancing scientific understanding of traumatic brain injury, one of the most complex and persistent health challenges faced by service members. To better study blast-induced brain damage, the Laboratory developed a research

platform, known as POSITRONIC — short for Platform to Optimally Study Injury and TRauma On Neural Integrity and Circuiting, that uses brain organoids to model cellular responses in real time. Paired with noninvasive imaging, the system enables researchers to observe how brain cells behave under stress and to test potential treatments or protective technologies in a controlled, ethical, and reproducible environment.

“Our goal is to develop a prototype platform to better understand the effects of mild blast-induced traumatic brain injury caused by repeated low-level blasts,” said Eyal Bar-Kochba, principal investigator on the project. “In doing so, we hope this research will help pave the way for advancements in preventative measures and improved diagnosis and treatment options.”

By bridging clinical assessment with cutting-edge biomedical research, the Laboratory is helping the military gain a more complete picture of warfighter health — one that not only improves accuracy and consistency in medical decisions but also drives new strategies for protection, recovery, and long-term resilience.

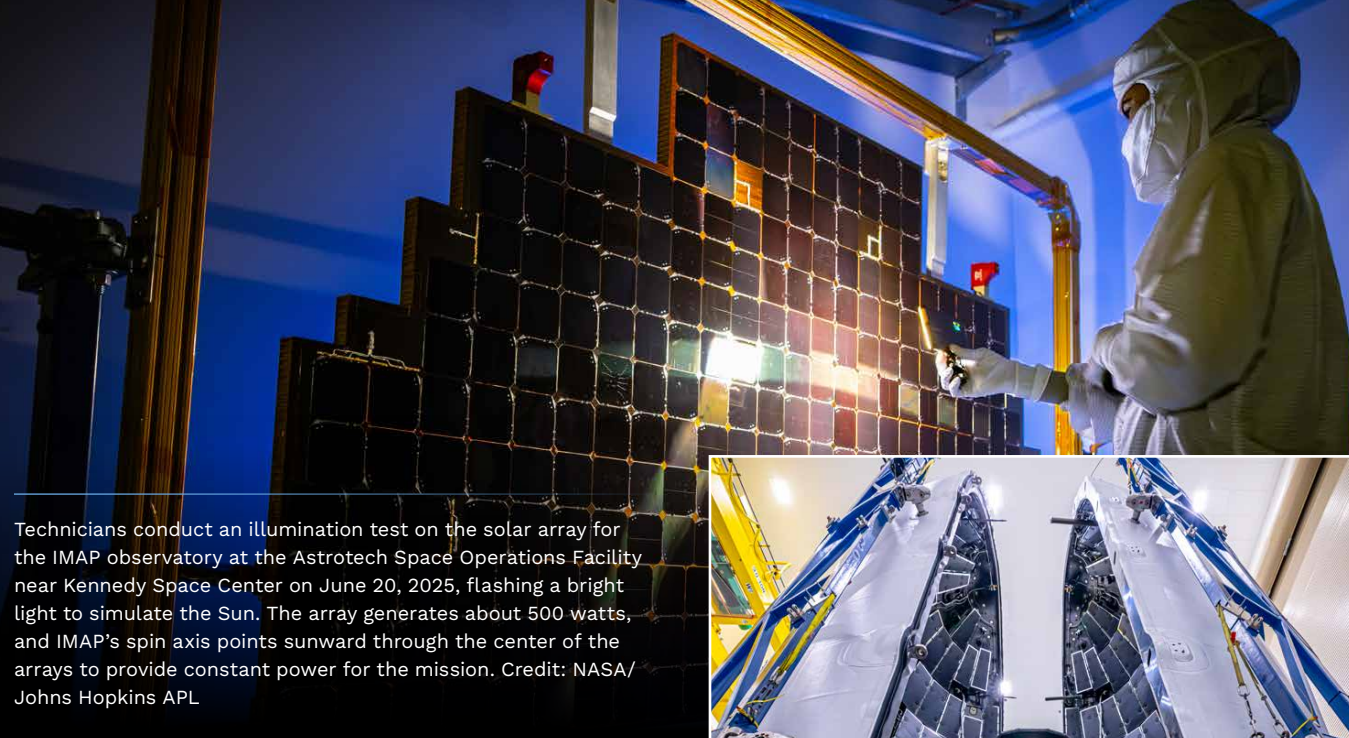


Eyal Bar-Kochba, principal investigator of POSITRONIC, uses digital holographic microscopy to noninvasively monitor cellular injury and study how brain cells respond to stress and potential treatment.

EXPLORING THE EXTREMES

APL's mission to solve complex challenges drives discoveries across extreme frontiers — from the blazing atmosphere of the Sun to the deepest Arctic oceans and the icy moons of the outer solar system. APL spacecraft, sensors, and scientific instruments are revealing how solar physics and space weather impact our world, while parallel efforts on Earth are shaping technologies to sustain human and robotic exploration and operations in extreme environments.

NASA's Interstellar Mapping and Acceleration Probe (IMAP) spacecraft, built by APL, is loaded for testing in NASA Marshall's X-ray and Cryogenic Facility thermal-vacuum chamber, simulating the harsh space environment. APL also provided spacecraft engineering and test expertise to help validate the observatory's performance before the spacecraft launched in September 2025.



Technicians conduct an illumination test on the solar array for the IMAP observatory at the Astrotech Space Operations Facility near Kennedy Space Center on June 20, 2025, flashing a bright light to simulate the Sun. The array generates about 500 watts, and IMAP's spin axis points sunward through the center of the arrays to provide constant power for the mission. Credit: NASA/ Johns Hopkins APL

Launching a New Wave of Discovery

In 2025, APL led two ambitious NASA missions that pushed the boundaries of space science and exploration: the Interstellar Mapping and Acceleration Probe (IMAP) and the Electrojet Zeeman Imaging Explorer (EZIE).

On Sept. 24, IMAP launched from Kennedy Space Center aboard a SpaceX Falcon 9 rocket.

IMAP will study the heliosphere, the Sun's magnetic bubble that shields our solar system, and help us develop a better understanding of space weather. IMAP is flying 10 instruments built by multiple organizations to study the solar wind, interstellar dust and other particles, magnetic fields, and ultraviolet light in space.

APL managed IMAP's development phase, built the spacecraft, and operates it. Working with institutions from around the world, APL integrated IMAP's instruments, subsystems, and components, thoroughly testing each one to ensure it would perform successfully in space.

Data from some of the spacecraft's instruments will support the IMAP Active Link for Real-Time system, which will broadcast frequent and reliable information to enhance space weather predictions.

The IMAP mission will also help researchers learn more about the solar wind and energetic particles throughout the heliosphere. Even though they likely play a role in the presence of life in the solar system, these particles can adversely affect humans in space and harm technological systems.



Anna Shin, an APL systems assurance manager, observes IMAP as it is encapsulated at the Astrotech Space Operations Facility, along with the Carruthers Geocorona Observatory and NOAA's Space Weather Follow On-Lagrange 1 spacecraft, inside a SpaceX Falcon 9 payload fairing on Sept. 16, 2025. Credit: BAE Systems



Blue Canyon Technologies technicians Davy Hong (left) and Dave Biancalana attach a solar array to the bus of the Electrojet Zeeman Imaging Explorer (EZIE) CubeSat. EZIE is the latest successful partnership between APL and Blue Canyon Technologies to develop agile, reliable solutions for cost-effective missions. Credit: Blue Canyon Technologies



“Through the IMAP and EZIE missions, APL is advancing our understanding of heliophysics. Together, these missions highlight what NASA, U.S. industry, and APL can achieve through strong partnerships and scientific excellence.”

— Robert D. Braun, APL's Space Exploration Sector Head

About six months earlier, on March 14, the trio of small satellites that comprise the EZIE mission also launched aboard a SpaceX Falcon 9 rocket, this time from Vandenberg Space Force Base in California. During its 18-month mission, the EZIE trio is flying in a pearls-on-a-string formation approximately 260 to 370 miles (420 to 590 kilometers) above Earth's surface.

Led by APL's Sam Yee, the mission's principal investigator, EZIE is determining the structure and evolution of Earth's electrojets — the currents flowing through the ionosphere that electrically couple our planet's magnetosphere to its atmosphere.

Electrojets — and their visible counterparts, auroras — arise when tremendous amounts of energy are transferred into Earth's upper atmosphere from the solar wind, streams of electrically charged particles that flow from the Sun into the solar system. Mapping the electrojets will shed light on the physics behind Earth's interaction with surrounding space — insights that will help us understand our own planet as well as any magnetized world in our solar system and beyond, while also improving our ability to predict space-weather events that can disrupt power grids, GPS, communications, and satellites people rely on every day.

“Through the IMAP and EZIE missions, APL is advancing our understanding of heliophysics,” said Robert D. Braun, head of APL's Space Exploration Sector. “Together, these missions highlight what NASA, U.S. industry, and APL can achieve through strong partnerships and scientific excellence.”

APL leads the mission for NASA. NASA's Jet Propulsion Laboratory in Southern California built each satellite's sole instrument, the Microwave Electrojet Magnetogram, and

Blue Canyon Technologies in Boulder, Colorado, provided the spacecraft, marking another successful partnership between APL and a commercial space firm.

Following the successful EZIE launch, NASA selected Dartmouth College and APL to begin developing the Cross-scale Investigation of Earth's Magnetotail and Aurora (CINEMA) mission, which will shed more light on the growing impacts of space weather by unlocking the secrets of the energy circulation through Earth's magnetotail.

Using a constellation of nine small satellites carrying three science instruments each, CINEMA will provide the most comprehensive view to date of the magnetotail and aurora and their roles in magnetospheric dynamics, including how energy is released and solar particles move through Earth's magnetic field, and reveal how storms on the Sun can trigger effects that reach all the way to the technologies we use on Earth. Dartmouth College serves as the



NASA competitively selected Dartmouth College and APL to develop CINEMA, a mission designed to improve understanding of the growing impacts of space weather.

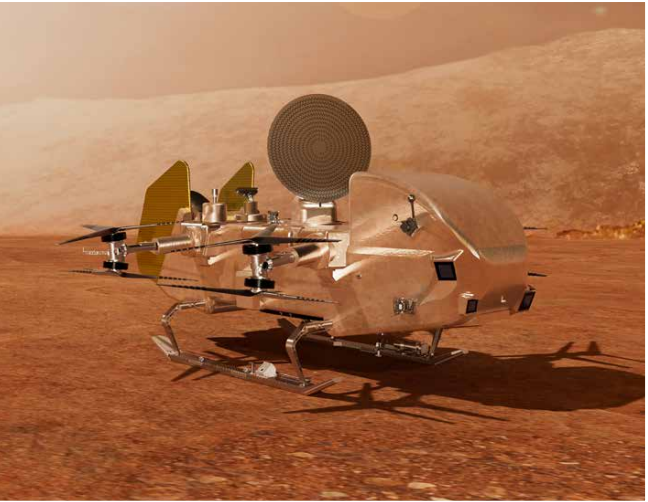
principal investigator institution, with APL managing the mission, providing critical instrumentation, and integrating the payload.

The Dragonfly mission, which APL leads and manages for NASA, also made significant strides toward launch with the successful completion of its Critical Design Review in April. Components for the car-sized, nuclear-powered rotorcraft and its scientific instruments — which will assess Titan’s habitability and search for the chemical building blocks of life as we know it — have been built and are undergoing rigorous development and test campaigns. The campaigns include aerodynamic wind-tunnel testing of Dragonfly’s rotors in Titan-like conditions and performance verification of the mass spectrometer and other instrument sensors. The larger integration and testing campaign is set to begin in early 2026, keeping the mission on track for launch in 2028 and Titan arrival in 2034.

APL’s next giant civil space leap, Dragonfly, embodies a game-changing approach to visiting other worlds in our solar system, pushing the boundaries of planetary exploration with a flying science laboratory that will take advantage

of Titan’s low gravity and dense atmosphere to examine sites across the moon’s diverse surface. Over an approximately three-year primary mission, Dragonfly will make repeated flights to dozens of geologic sites, collecting and analyzing samples to investigate the chemical processes that may resemble those that led to life on Earth.

Throughout 2025, APL also engaged a broader set of government and commercial space partners, expanding its national impact to complement larger programs such as Dragonfly and IMAP. These efforts span a targeted set of focus areas, including cislunar infrastructure and lunar surface systems, space weather missions including analysis and forecasting, and planetary defense. Many of these projects are pursued in close collaboration with civil and national security sponsors and industry partners, enabling rapid technology maturation while advancing shared understanding of the space environment. Together, these partnerships enhance APL’s technical depth, strengthen its role across the space ecosystem, and ensure continued impact to the nation in an increasingly dynamic space domain.



(Left) An artist’s rendering shows NASA’s Dragonfly rotorcraft at a landing site on Saturn’s moon Titan. (Below) The Dragonfly team gathered after completing the Critical Design Review in April 2025, marking the transition into full-scale fabrication, integration, and testing for the car-sized, nuclear-powered mission that will fly between dozens of sites to investigate the chemical origins of life.



An artist's impression shows Parker Solar Probe during its closest approach to the Sun on Dec. 24, 2024. Designed, built, and operated by APL, the spacecraft set records by flying within 3.8 million miles (about 6.1 million kilometers) of the solar surface while moving 430,000 miles per hour (687,000 kilometers per hour). Credit: NASA/Johns Hopkins APL

Uncovering the Mysteries of Space Weather and the Sun

While IMAP studies the Sun’s influence from afar, APL is also relying on a mission that ventures much closer — the Parker Solar Probe — to shed light on the solar activity that drives space weather. APL complements these observations with tabletop exercises that help experts prepare for disruptions to satellites, communications, and power grids. On a record-breaking pass by the Sun in late 2024, NASA’s Parker Solar Probe captured stunning images from within the Sun’s



A photo taken from the International Space Station of the aurora borealis streaming above southeastern Manitoba. Auroras occur when particles and energy from the Sun interact with Earth’s magnetic field. By studying these processes through missions such as IMAP and Parker Solar Probe, APL works to better understand and predict space weather to help protect satellites, communications, and power systems. Credit: NASA

An image captured by Parker Solar Probe’s Wide-Field Imager for Solar Probe (WISPR) during the Dec. 25, 2024, flyby shows the solar wind streaming out from the Sun’s corona, providing new insight into the drivers of space weather. Credit: NASA/Johns Hopkins APL/Naval Research Laboratory

atmosphere. These images — taken closer to the Sun than any spacecraft has been before — are helping scientists better understand the Sun’s influence across the solar system, including events that can affect Earth.

“Parker Solar Probe has transported us into the dynamic atmosphere of our closest star,” said Nicky Fox, associate administrator for NASA’s Science Mission Directorate. “With our own eyes, we are witnessing where space weather threats to Earth begin. Parker Solar Probe data will help us vastly improve our space weather predictions to ensure the safety of our astronauts and protect our technology on Earth and throughout the solar system.”

Designed, built, and operated by APL, Parker started its closest approach to the Sun on Dec. 24, 2024, flying just 3.8 million miles (about 6.1 million kilometers) from the solar surface. As it skimmed through the Sun’s outer atmosphere, called the corona, it collected data with its array of scientific instruments, including the Wide-Field Imager for Solar Probe, or WISPR.

WISPR revealed intricate structural details in the corona and solar wind, information that will lead to better understanding of these high-energy material outbursts and how, when combined with magnetic currents from the Sun, they



Members of the Parker Solar Probe mission team from NASA, APL, and partner institutions surround the Robert J. Collier Trophy during the ceremony to bestow the prestigious aerospace award on June 12, 2025. Credit: National Aeronautic Association

Parker Team Secures the Collier Trophy

Led by APL in partnership with NASA, academia, and industry collaborators, the Parker Solar Probe mission team received the National Aeronautic Association’s prestigious Robert J. Collier Trophy. The team was lauded for its unprecedented achievements in advancing humanity’s understanding of the Sun and for the engineering breakthroughs that made that exploration possible, including:

- An ultradurable thermal protection system that withstood temperatures around 2,500 degrees Fahrenheit (1,371 degrees Celsius)
- Actively cooled solar arrays protected by autonomous software that prevents over-exposure to intense solar energy while powering the spacecraft
- A fully autonomous flight system that can manage spacecraft operations, orientation, and configuration for months at a time



Dipak Srinivasan, a program area manager in APL’s Space Exploration Sector, served as exercise manager for the nation’s first end-to-end space weather tabletop exercise, cosponsored by NOAA, NASA, NSF, and FEMA. The event brought nearly 80 players and observers to APL to examine coordinated federal response to severe space weather, and the results were published in 2025.

generate auroras, strip planetary atmospheres, and induce electric currents that can overwhelm power grids and affect communications at Earth.

How to deal with those effects in our local space environment was the topic of the nation’s first end-to-end Space Weather Tabletop Exercise, the results of which APL published in 2025.

Sponsored jointly by the National Oceanic and Atmospheric Administration (NOAA), NASA, the National Science Foundation (NSF), and the Federal Emergency Management Agency (FEMA), the APL-hosted exercise simulated severe solar events, such as coronal mass ejections, and tested the government’s interagency coordination, response protocols, and communications across a wide range of industry and critical infrastructure sectors. The findings were deemed so significant that FEMA and NOAA modified their operational reporting protocols within 24 hours of the exercise, coinciding with the “Mother’s Day Gannon Storm” of 2024. This response marked an important milestone in the nation’s preparedness for severe space weather.

Leveraging its expertise in space weather research, APL developed the content for the exercise in collaboration with the sponsoring agencies; the Laboratory also coordinated and executed the exercise and collected and distributed the data and results. Among several key findings and recommendations, participants uncovered needs for better coordination between agencies to warn of impending space weather impacts on critical infrastructure, awareness across all levels of government to ensure rapid, effective responses to space weather incidents, and opportunities to improve forecasting and early-warning capabilities, including placing spacecraft closer to the Sun.

Advancing Operational Resilience

From the ocean floors to the polar caps, APL is developing technologies that strengthen human and system performance in some of the harshest conditions on Earth. Researchers are advancing protective materials, sensors, and systems that safeguard people and equipment against cold, pressure, and other environmental extremes. Whether enabling divers to operate safely at depth or preventing ice from damaging critical infrastructure in the Arctic, these innovations extend mission endurance and reliability when failure is not an option.

Under direction of the Office of Naval Research, APL is providing technology integration, research, development, and programmatic support for the Deep Sea Expeditionary No Decompression (DSEND) project — an effort to design a next-generation dive suit that significantly improves mobility, safety, and flexibility for military divers.

The Laboratory is also investigating how subtle changes in biometric data can predict hidden physiological threats. In partnership with the Naval Medical Research Command and its Naval Advanced Medical Development program, APL led the first Johns Hopkins Medicine-approved hyperbaric human-subjects study at the University of Maryland’s Neutral Buoyancy Research Facility. This effort is part of a campaign to test and validate new physiological monitoring systems in progressively harsher conditions, paving the way for health insights in extreme environments across the defense enterprise.

“We want to move from explaining why something went wrong after the fact to predicting and preventing problems before they happen,” said Austin Veith, a biomedical engineer who leads some of the Laboratory’s human-subjects test and evaluation efforts. “That’s what

All About the DSEND Dive Suit

- Target depth: 1,000 feet
- Combines the mobility and deep-dive capabilities of surface-supplied and atmospheric suits
- Novel technologies include a high-definition display that provides 3D spatial awareness via sonar, infrared vision, wireless communication, and mixed-reality capabilities
- Relays complete telemetry information to surface operators

The suit is designed for walking on the sea floor and equipped with rotating and articulating joints that allow freer, more natural movement. In a significant first for an atmospheric dive suit, APL plans to produce the articulating joints through additive manufacturing. And with a modular design, the suit can be form-fitted to divers of different body shapes and sizes and easily packaged and transported on commercial flights.



The Deep Sea Expeditionary No Decompression (DSEND) prototype atmospheric diving suit is shown above. The suit was tested in water at the U.S. Navy Experimental Diving Unit and demonstrated at the University of Maryland in June 2025 with APL project manager Chad Klinesteker (left) and program manager Alex Cheij. Credit: Charlie Hanner (DSEND image at left)

makes this research so important, not just for Navy divers but for anyone the nation sends into environments where the human body is under extraordinary stress.”

The team focused on developing the Integrated Monitoring System (IMS), which pairs wearable physiological sensors with a data pipeline to capture, process, and transmit diver vital signs. The goal is to enable reliable monitoring of heart rate, blood oxygenation, body temperature, and related indicators underwater, providing actionable information to surface commanders. Because no gold-standard measurements exist in underwater environments, the team developed a rigorous, tiered test campaign to build confidence in system performance. Testing progressed from dry-land validation against clinical-grade instruments, to shallow-water trials at the University of Maryland’s Neutral Buoyancy Research Facility, and to dry hyperbaric testing at the University of Maryland Medical Center to isolate the effects of pressure.

The program’s next steps include wet hyperbaric testing, cold-water immersion and hypoxia human subjects research, and open-ocean dives, all leading up to Navy Experimental Diving Unit evaluations. Each phase will probe new stressors, refine data pipelines, and explore how information should be displayed for both divers and commanders.

Long-term, predictive models could anticipate when a diver is approaching unsafe fatigue, identify early signs of decompression stress, or even forecast performance in upcoming missions. Those insights could allow commanders to adjust schedules, swap operators, or intervene before risks escalate.

Just as APL is advancing technologies to keep divers safe and effective under water, the Laboratory is also helping the government strengthen operations at another extreme — in the Arctic. APL researchers are supporting the Defense Advanced Research Projects Agency’s Ice Control for Cold Environments (ICE) program, an effort to develop solutions to the operational challenges of extreme cold by harnessing the power of biomolecules. APL has played a significant role in ICE through its Bio-Optimized Regulation of Environmental Ice for Arctic Supremacy (BOREAS) program, which began as a collection of internally funded projects dating back to 2020.

To support the effort, an APL team, led by polymer chemist Joel Sarapas, developed a digital library of bioinspired synthetic polymers, which can provide novel capabilities by altering the behavior of a biomolecule or material.

The team has uncovered dozens of molecules with ice-affecting capabilities — both those that encourage (ice-nucleating) and inhibit (antifreeze) ice formation. One

is lactobionic acid, a derivative of lactose typically used in cosmetics and skincare products that also happens to efficiently spur ice formation when added to a polymer.

Working in parallel, molecular biologist Will Stone has led creation of a second library focused on ice-affecting proteins. Stone’s team is working to enhance these proteins by combining them with ice-nucleating and antifreeze properties, an approach that seems counterintuitive but could actually create stronger adhesion by stabilizing collections of small ice crystals and preventing their aggregation into larger, less adhesive crystals.

Starting with 36 well-studied antifreeze and ice-nucleating proteins from scientific literature, the team used artificial intelligence to screen massive databases for other sequences with similar traits. From 14,000 candidates the researchers pulled 108 proteins, each classified as likely antifreeze or ice-nucleating, to create a library of 11,664 unique protein pairs.

“This type of research could be a real game-changer for military operations in the Arctic,” said Leslie Hamilton, program manager for Science of Extreme and Multifunctional Materials. “If we can reliably control ice formation in different conditions and on different surfaces, we could unlock innovative solutions for challenges associated with infrastructure, transportation, and medical needs in cold environments.”



U.S. Army paratroopers descend onto Maletmute Drop Zone at Joint Base Elmendorf-Richardson, Alaska, during Arctic Aloha 26, demonstrating readiness in extreme environments. APL developed a digital library of bioinspired synthetic polymers that can control where ice does or does not nucleate, which could one day help military operators manage ice formation across different conditions and surfaces. Credit: U.S. Army

Cislunar space, which comprises the region between Earth’s geosynchronous orbit and the Moon, as well as the Earth-Moon Lagrange points, is an emerging domain for national security, scientific exploration, resource mining, and manufacturing. APL plays a leading role in advancing cislunar capabilities, including leading NASA’s Lunar Surface Innovation Consortium to help shape technologies and concepts for sustained operations beyond Earth orbit. Credit: NASA

Preparing for Cislunar Space Operations

As the United States aims for a permanent presence on the Moon, cislunar space — which comprises the region between Earth’s geosynchronous orbit and the Moon, as well as the Earth-Moon Lagrange points — is an emerging domain for national security, scientific exploration, resource mining, and manufacturing. APL is shaping the nation’s next lunar chapter by collaborating with government and industry to advance the technologies, partnerships, and infrastructure for safe and sustained operations beyond Earth orbit.

Central to this effort is APL’s role as systems integrator for NASA’s Lunar Surface Innovation Initiative (LSII), supporting the Space Technology Mission Directorate in advancing technologies needed for an enduring lunar presence. As part of this role, APL leads the Lunar Surface Innovation Consortium (LSIC), which has grown from a small gathering of experts in 2020 into a thriving community of more than 3,500 members from over 1,200 organizations. LSIC connects government, industry, and academia to identify technology gaps and accelerate solutions for lunar surface missions and sustained activity in cislunar space.

APL is also applying deep systems engineering expertise through LSII to support the development of technologies for regolith processing, dust mitigation, surface power, and durable materials — capabilities essential for long-term human and robotic operations on the Moon. These efforts



Participants engage at the Lunar Surface Innovation Consortium (LSIC) Spring Meeting, held May 20-22 at APL. The 2025 meeting marked LSIC’s fifth anniversary and brought the community together for NASA updates, technology demonstrations, and collaboration focused on advancing lunar surface capabilities.

complement the Laboratory’s broader work to ensure reliable communications and navigation capabilities far beyond Earth orbit.

With a broad and distinguished base of cislunar experts and a demonstrated ability to work across the civil and national security space domains, APL plays a central role in advancing understanding and operations in the cislunar domain. APL integrates research and applied engineering to address challenges in cislunar operations — from space domain awareness and resilient infrastructure to navigation, communications, and exploration architectures — helping guide the engineering, operational, and exploration communities toward secure and sustainable activity between Earth and the Moon.

APL's Satellite Communications Facility is modernizing antennas and ground systems to support lunar and cislunar missions, providing a flexible hub for tracking and communications with commercial lunar landers.



APL Space Exploration Sector Head Robert D. Braun addresses attendees at the 2025 Cislunar Security Conference.

Securing the Space Between: Sixth Annual Cislunar Security Conference

The sixth annual Cislunar Security Conference, which is the nation's largest event focused exclusively on the cislunar domain, brought over 400 experts together from defense, intelligence, industry, and academia to discuss how to ensure freedom of access and sustainable operations beyond Earth orbit.

The three-day event featured keynote presentations from Stefanie Tompkins, the director of the Defense Advanced Research Projects Agency (DARPA), and NASA Associate Administrator Jim Free, and included discussions about position and navigation in cislunar space, domain awareness, and supporting technologies to enable cislunar operations.



Additionally, APL is advancing an integrated ecosystem of capabilities for cislunar space through a Collaborative Testbed that brings together complementary technologies and partners from government, industry and academia. The Collaborative Testbed integrates situational awareness capabilities, autonomous mission operations, and onboard navigation to improve space systems and ensure a realistic proving ground for future missions. These capabilities, when paired with deep expertise from APL and its partners, enable, and strengthen decision superiority for our nation's space warfighters.

At APL's Satellite Communications Facility — opened at the dawn of the Space Age — engineers are modernizing infrastructure to meet the demands of lunar and cislunar missions. With its advanced antennae, the facility serves as an essential, adaptable tracking and communications hub for the growing number of NASA-directed commercial lunar landers, including Firefly Aerospace's Blue Ghost Mission 1 — a lunar lander mission that launched in January. The facility will receive data during both cruise and lunar surface operations.

"APL has provided communications services for lunar missions before," said Michael Norkus, who leads the operations team of the Satellite Communications Facility. "We're eager to support U.S. industry as they perform science and technology objectives that advance the capabilities and interests of our nation."



The Polylingual Experimental Terminal (PEXT) technology demonstration, codeveloped by NASA and APL, is advancing wideband links that can connect across government and commercial networks, supporting more flexible and efficient near-Earth communications for future missions. Credit: NASA

Sensing and Communicating From Space

Reliable communication and precise remote sensing are essential for every mission venturing into space. APL is shaping next-generation technologies designed to improve how spacecraft detect, process, and share information across vast distances. By linking innovations in small satellites, wideband communications, and autonomous signal processing, Laboratory innovators are creating systems ready to handle the demands, from cislunar mission networks to deep space.

In partnership with Blue Canyon Technologies, APL is leveraging commercial satellite platforms to deliver reliable, cost-effective sensing and data collection for space science and national security missions. The collaboration exemplifies how commercial innovation combined with deep technical expertise can accelerate mission timelines and expand capacity for space-based observation.

APL also led the development of the Polylingual Experimental Terminal (PEXT), a wideband, multilingual communications terminal that allows spacecraft to seamlessly operate across government and commercial networks for the first time. Launched on July 23 aboard a SpaceX Falcon 9 rideshare mission, PEXT enhances a spacecraft's communications subsystem, enabling mission controllers to track and exchange data more efficiently across a broad range of networks and frequencies.

PEXT works similarly to cellular network technology, where a phone has a primary wireless network but can roam to networks managed by other companies without

interruption. NASA and APL aim to provide a comparable framework, allowing spacecraft that are equipped with the terminal and flying in low Earth orbit to connect seamlessly to relay satellites running on commercial and government networks.

"This demonstration brings unprecedented capability to new space missions by enabling communications that are untethered from the constraints of individual service providers and enabled by multilingual access to hybrid networks," said Chris Haskins, principal investigator for PEXT at APL. "It also shows how government, academia, and industry can partner effectively to develop and demonstrate groundbreaking and critical space capabilities."



Hardware for PEXT undergoes environmental testing at APL, helping validate a wideband communications approach that can link spacecraft to both government and commercial networks.

A CULTURE OF INNOVATION

From incubating bold research proposals and developing the next generation of leaders to building collaborative workspaces, APL fuels creativity and novel ideas at every level.

APL's emphasis on innovation lays the groundwork for capabilities that deliver value to sponsors. Purpose-built lab spaces enable teams to explore high-risk ideas, mature emerging technologies, and rapidly transition successful concepts into sponsor-ready solutions. To complement this infrastructure, the Lab sustains a portfolio of strategic investments to foster innovative approaches, catalyze new ideas, and accelerate their path from concept to impact. The Independent Research and Development (IRAD) program, Project Catalyst, and Janney Grants are three key programs in this portfolio.

IRAD

The IRAD program is a cornerstone of innovation at APL, enabling the Lab's 13 mission areas each year to pursue high-impact, mission-relevant research and development with the potential to address critical national challenges. Spanning basic research through system concept formulation, IRAD projects mature promising technologies into novel capabilities that can transition to sponsors and deliver real-world mission impact. The process is highly competitive. Roughly 1,600 IRAD proposals were submitted in 2025, and more than 400 were funded. Some of the most impactful IRADs from 2025 include:

Discovery of Infrared Transparent Materials (DIRT)

The hypersonic community requires infrared-transparent window materials that can withstand the extreme thermal environments encountered at speeds exceeding Mach 5, yet few materials meet both performance and manufacturability requirements. To address this gap, APL researchers developed a generative artificial intelligence (AI) platform that enables rapid design, synthesis, and testing of new high-temperature optical materials, dramatically speeding up development of advanced, heat-resistant windows for hypersonic and related applications.



Andy Goers, an APL optical physicist, works in the Hypersonic Optical Test Lab. This facility is a versatile space where APL researchers use a high-power CO₂ laser, infrared pyrometry cameras, wavefront sensors, and a boresight-error testbed to evaluate and characterize advanced hypersonic materials and coating concepts.

Increasing Fleet Readiness with Digital, Cyber Secure Advanced Manufacturing Tools

Electronic component failures are the leading cause of fleet outages in critical warfighting systems, which are often compounded by long lead times and limited design and repair documentation. Aerosol-jet-based advanced electronics manufacturing offers an emerging solution, enabling rapid fabrication and deployed repair of printed circuit boards. Working with the original equipment manufacturer, APL developed an Electronics Advanced Manufacturing (eAM) machine by modifying an HD2 aerosol jet additive printer to integrate subtractive and post-processing capabilities into a single, user-friendly system.

The Lab also developed the Agile Manufacturing eXchange (AMX), which is compatible with the Navy advanced manufacturing environment, to provide the digital tools and data required for a minimally trained technician to manufacture at the point of need. The eAM machine was connected to the AMX to remotely deliver the capability to complete complex electronic repairs without having to deploy an expert. This capability is the culmination of four years of work to reimagine the repair of complex systems at the edge.

A drill bit machines a metal coupon inside a hybrid additive manufacturing system in APL's Advanced Manufacturing Facilities, where precision fabrication and rapid prototyping accelerate mission-ready solutions for national security and critical challenges.



Bobby Mueller, an additive manufacturing process engineer, operates a FormAlloy metal 3D printer in APL's Advanced Manufacturing Facilities.

Advanced Manufacturing Facilities

APL's Advanced Manufacturing Facilities encompass approximately 95,000 square feet and provide end-to-end, AS9100-certified capabilities to develop mission-ready hardware for classified and unclassified programs. By integrating design, fabrication, testing, and assembly, the labs enable teams to rapidly transition concepts into qualified systems for applications ranging from deep-ocean platforms to spaceflight.



CYPRESS Lab

Cyber-Physical Resilient Systems Solutions (CYPRESS) is a laboratory at APL with small-scale industrial control systems and associated equipment. The facility has both water and power environments. CYPRESS has been critical to the development of cybersecurity mitigations and has accelerated critical infrastructure cyber defense against Volt Typhoon.

Contextual Alert Risk Prioritization (CARP)

CARP is a machine learning system APL designed and prototyped to optimize alert handling inside Navy cyber-defense platforms. The tool works by analyzing alerting trends, identifying patterns, and considering mission context to prioritize alerts and ensure that high-risk threats receive immediate attention. This approach significantly boosts the efficiency and effectiveness of cyber defenders, enabling them to rapidly detect and respond to critical security incidents. In testing, CARP matched human expert alert rankings better than baseline and state-of-the-art techniques.

Project Catalyst

Project Catalyst is a Lab-wide science and technology grant program that provides staff funded opportunities, sometimes over multiple years, to test critical assumptions, investigate phenomena, and push the boundaries of knowledge and what is possible. Since its launch, the program has awarded nearly 700 grants ranging from \$10,000 to \$500,000, with 77 grants awarded in FY 2025 alone.

Project Catalyst in Action: Neural Networked Clock Ensemble for Coherent Sensing

APL developed an ultrastable, low-SWAP (size, weight, and power) timing solution that improves oscillator performance by two to three orders of magnitude among spatially distributed radar receivers. This capability supports next-generation multisatellite synthetic aperture radar architectures, delivering higher-resolution 3D imaging and more precise motion measurement that directly boost target identification, battle-space awareness, and rapid decision-making in contested missions while enabling more flexible, resilient, and scalable radar constellations using conventional radio frequency links.

APL staff gather for BOLD Catalysts, an annual event celebrating Project Catalyst — an innovation program to empower staff to pursue bold, high-risk ideas. The program funds early-stage concepts through three grant tiers, helping teams test transformational ideas and position promising work for sponsor adoption.



Janney Grants

APL's Janney Grants empower staff to engage and collaborate with the broader science and technology ecosystem, both domestically and globally. A key part the Lab's overall strategy, this collaboration helps APL maintain awareness of emerging technologies and stay on the cutting edge of key competency areas for sponsors.

Janney Grants in Action: AI Imaging for Dual-Use Applications

Chiman Kwan, an electrical engineer and IEEE fellow — received a Janney Grant to collaborate with Professor Julia Chung at National Cheng-Kung University in Taiwan. The partnership focused on advancing AI and machine learning algorithms for medical imaging analysis, with planned transition of these techniques to missile detection applications.



Chiman Kwan, a senior professional staff member at APL, advances infrared modeling and imaging for hypersonic and Tomahawk-related applications. A longtime leader in signal and image processing, he holds 15 patents, has published extensively, and is a fellow of multiple professional societies.



(From left) APL staff members David Casselbury, Marie Chau, and Neil Joshi are using AI to monitor the use of 3D printers to create nefarious objects.

Central Spark

Central Spark is APL's 24/7 innovation space, supporting rapid experimentation and cross-sector collaboration with minimal barriers. The 9,000-square-foot facility combines tools for rapid fabrication, electronic circuitry, virtual and augmented reality, and human-centered design, and it supports more than 3,000 staff visits each week. Work in Central Spark ranges from exploratory concepts to applied solutions, including a Janney-funded project that used machine learning to flag potentially harmful 3D-printable designs — and demonstrated how the space enables creativity and responsible innovation.



An APL staff member operates a state-of-the-art 3D printer in Central Spark, where accessible additive manufacturing tools enable hands-on prototyping and accelerate ideas from concept to real-world application.



Researchers work inside the Ralph D. Semmel Center for Innovation, a 263,000-square-foot facility designed to foster collaboration across disciplines and accelerate mission-driven research in areas including advanced materials, biotechnology, quantum science, and microelectronics.

Innovation Infrastructure

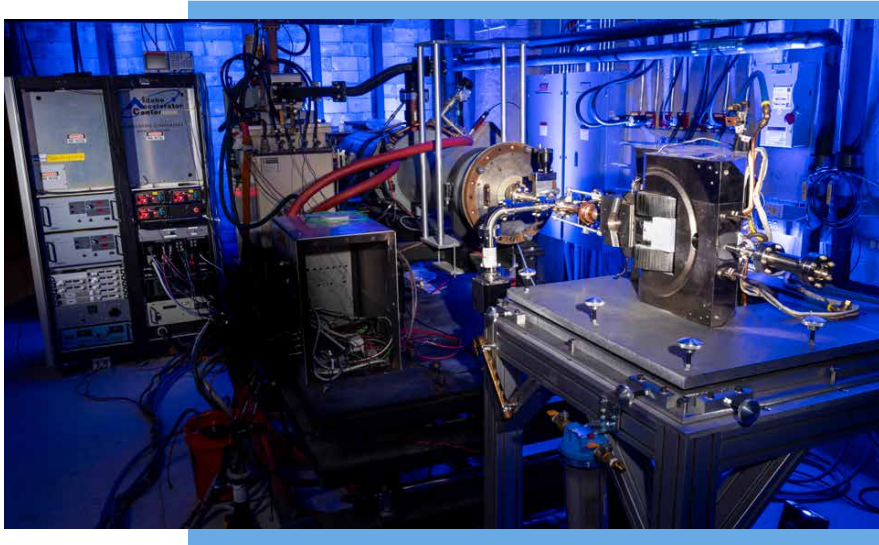
Making critical contributions requires taking risks and running experiments — work that is best done in labs and technical facilities. APL has created and maintains several specialized facilities, many of which are unique in the nation. Here are some of APL’s notable research and collaboration spaces:

Ralph D. Semmel Center for Innovation

Named in honor of Director Emeritus Ralph Semmel, the Semmel Center is a 263,000-square-foot research facility designed to spark innovation and collaboration in mission-related research and development. It offers 90,000 square feet of laboratory space for advanced materials, biotechnology, quantum science, power and energy technologies, and microelectronics, as well as reconfigurable work areas for more than 650 scientists and engineers.

Linear Accelerator Facility

The 4,000-square-foot Linear Accelerator (LINAC) Facility houses a 25 MeV S-band accelerator, a heavily shielded hall, a radiochemistry lab, and a dedicated Controlled LINAC Irradiation of Quantum Experiments test stand with a dilution refrigerator that cools samples to ~10 mK. This is the first and only facility in the world that has coupled an electron accelerator and a dilution refrigerator, making it an ideal place to study radiation effects in quantum computing devices.



APL’s Linear Accelerator Facility houses a 25 MeV S-band accelerator and the world’s only coupled electron accelerator and dilution refrigerator, enabling unique experiments to study radiation effects in quantum computing devices.

Biosafety Lab

APL’s Biosafety Level 3 laboratory is a 2,400-square-foot space for conducting research in bacteriology, virology, bioaerosol sciences, genomics, nanoparticle science, and more. The facility is the largest active chamber of its kind in the country, enabling recapitulation of the natural environment and allowing accurate testing and measurement of the physical, biological, and chemical properties of live agents.

Combat Systems Cyber Warfare Analysis Lab (CSCWAL)

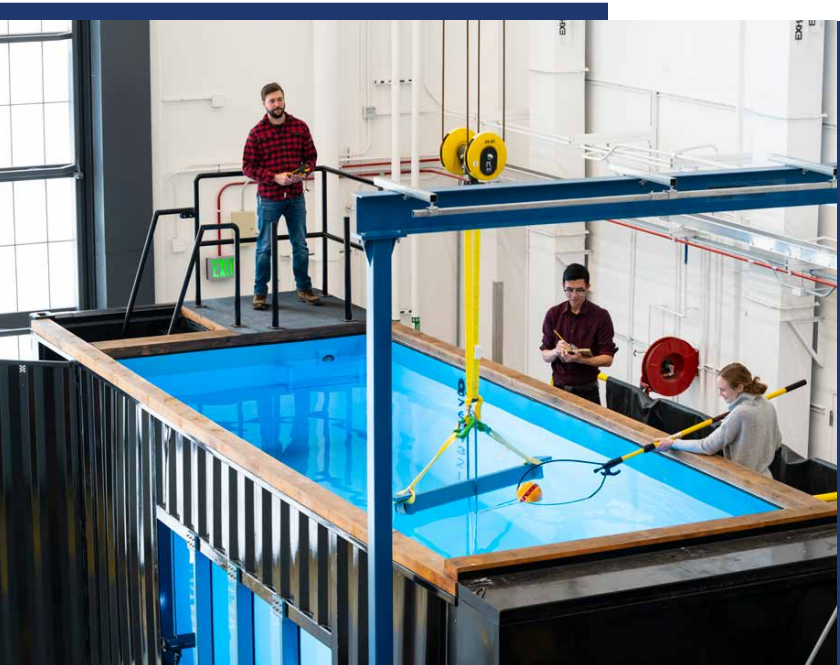
This laboratory provides a stand-alone classified environment for the development, integration, and testing of cyber capabilities to support air and missile defense systems. The lab serves as the primary space for testing cyber effects, evaluating and validating cyber vulnerabilities, and developing cyber defense systems against nation-state adversaries. Because of the unique nature of CSCWAL and the array of capabilities available, APL has been able to provide several significant contributions to our sponsors.



APL staff members focus on a live dashboard in CSCWAL. From tabletop risk assessment drills to rapid prototyping of cyber defense concepts, this facility enables end-to-end work — design, testing, integration, and fielding of secure systems; supply chain hardening; reverse engineering of threats; and software assurance — so national security capabilities stay protected.

Satellite Communications Facility

Established in 1961 to support the command and telemetry requirements of the world’s first satellite navigation system under contract to the U.S. Navy, the APL Satellite Communications Facility has provided support for a broad range of space-flight missions for more than six decades. The facility consists of two independent operational antennas, one at 16 feet (5 meters) and another at 60 feet (18.3 meters). It offers commanding, ranging, telemetry, and Doppler tracking services for spacecraft missions in locations ranging from low Earth orbit to deep space, with a communications range approximately 2.5 times the average distance between Earth and the Sun.



10,000-Gallon Saltwater Test Tank

This 10,000-gallon test tank serves as a controlled setting for evaluating maritime sensors and platforms and accelerating the integration and testing of new remotely operated vehicle technologies. The salinity of the tank is maintained to match the area of interest in the ocean to enable testing where density, conductivity, and corrosion are important.

Engineers conduct testing in the 20-foot saltwater tank, using the facility’s overhead crane to lower instrumentation and evaluate sea-based sensors and system performance in a controlled environment.

TECH TRANSFER

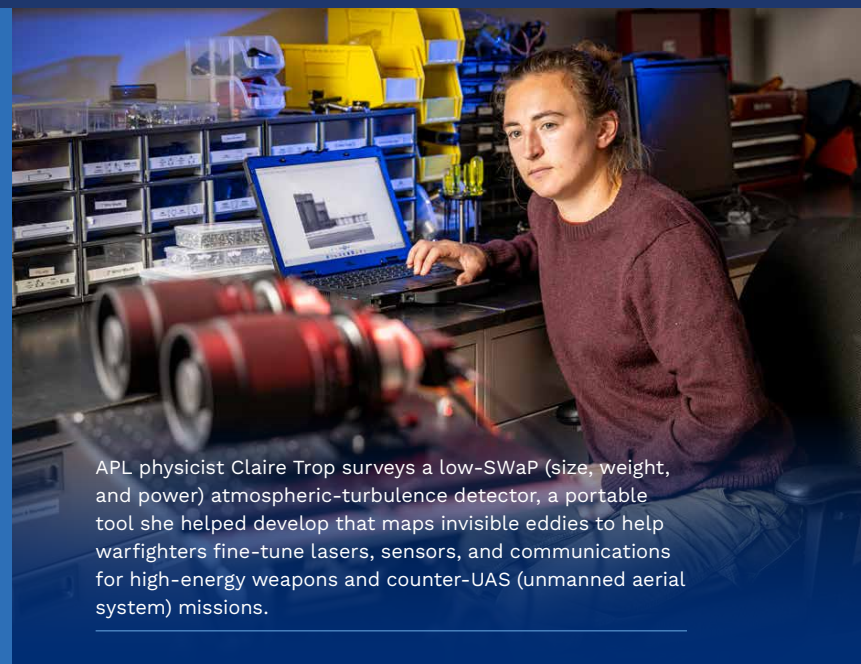
With a large portfolio of cutting-edge intellectual property and a team of experienced licensing staff, APL's Tech Transfer offers streamlined access to technological innovations made at the Laboratory.

Intellectual Property and Patents

Since Tech Transfer was established in 1999, APL has logged more than 8,700 IP disclosures and executed over 1,100 license and other like agreements.

In FY 2025:

597 IP disclosures received
22 U.S. patents issued
101 licenses and agreements
145 commercialized products



APL physicist Claire Trop surveys a low-SWaP (size, weight, and power) atmospheric-turbulence detector, a portable tool she helped develop that maps invisible eddies to help warfighters fine-tune lasers, sensors, and communications for high-energy weapons and counter-UAS (unmanned aerial system) missions.

The Innovation Life Cycle: Research to Application

Tech Transfer drives game-changing impact by responsibly transferring knowledge and technology, partnering strategically, and discovering external advances that complement APL's mission. Here are three projects that showcase Tech Transfer's collaboration with innovators and programs through three pathways: transfer, partner, and discover.

Transfer. With strategic investment from Tech Transfer, senior APL chemist Kelly Van Houten and her team created a proof of concept for a color-changing test strip to signal the presence of any fentanyl analog instantly. Tech Transfer then licensed the technology to a U.S. company that is now evaluating the strip's commercial viability.

Partner. Over the past 25 years, APL's Frontier Radio has been used on space missions exploring regions from the Sun to Mars and beyond, including NASA's Europa Clipper and Parker Solar Probe missions. Tech Transfer facilitated a commercial license and five-year master service agreement with Rocket Lab in 2020. Today, Rocket Lab builds the electronics for the technology, while the Lab supports software updates. This collaboration has reduced system costs and delivery timelines by a factor of 10, accelerating the path from the Lab to orbit from three years to less than six months.

Discover. Through a strategic collaboration with Microsoft, APL researchers are advancing the application of artificial intelligence (AI) across multiple domains. One effort applies AI and scene-mapping technologies to transform robots from requiring many commands into autonomous teammates capable of planning, coordinating, and executing missions in disaster response and battlefield environments leveraging Microsoft's Azure platform. In addition, APL is leveraging its expertise in closed-loop discovery of novel superconductors to collaboratively investigate whether Microsoft's MatterGen generative AI tool can predict, make, and measure novel oxide superconducting materials. This capability could be further evolved to create designer materials to meet specific performance needs, reduce reliance on rare earth elements, or provide alternatives to critical materials that are vulnerable to supply chain disruptions.

2025 APL Start-Ups: Accelerating Commercial Pathways

Nuquantic is advancing environmental monitoring technologies through a partnership with Early Charm, an incubator of start-up companies based in Baltimore, Maryland. Nuquantic licensed APL's portable environmental DNA (eDNA) filtration system and, with APL Tech Transfer's support, secured a \$300,000 Maryland Innovation Initiative award from the Maryland Technology Development Corporation (TEDCO) to accelerate commercialization.

BIOPAC Medical Systems LP is working a novel neural blockade monitoring device to improve real-time assessment of regional anesthetic effectiveness. The company stems from a licensing partnership between APL, Johns Hopkins Medicine, BLOCKsynop, Inc., and BIOPAC Systems and builds on APL-originated neural block monitoring technology developed by former APL engineer Wayne Sternberger. To accelerate commercialization and clinical translation, the venture has support from the Maryland Innovation Initiative and with a National Science Foundation Small Business Innovation Research grant.

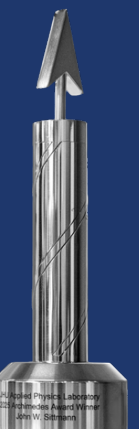
Deep Root Biolabs is commercializing a patent-pending platform that integrates plant and microbial systems for sustainable agriculture by strengthening soil health and increasing crop resilience, environmental remediation, and critical mineral recovery. Founded by former APL researcher John Sittmann, the company translates fundamental biological processes into practical, scalable solutions.



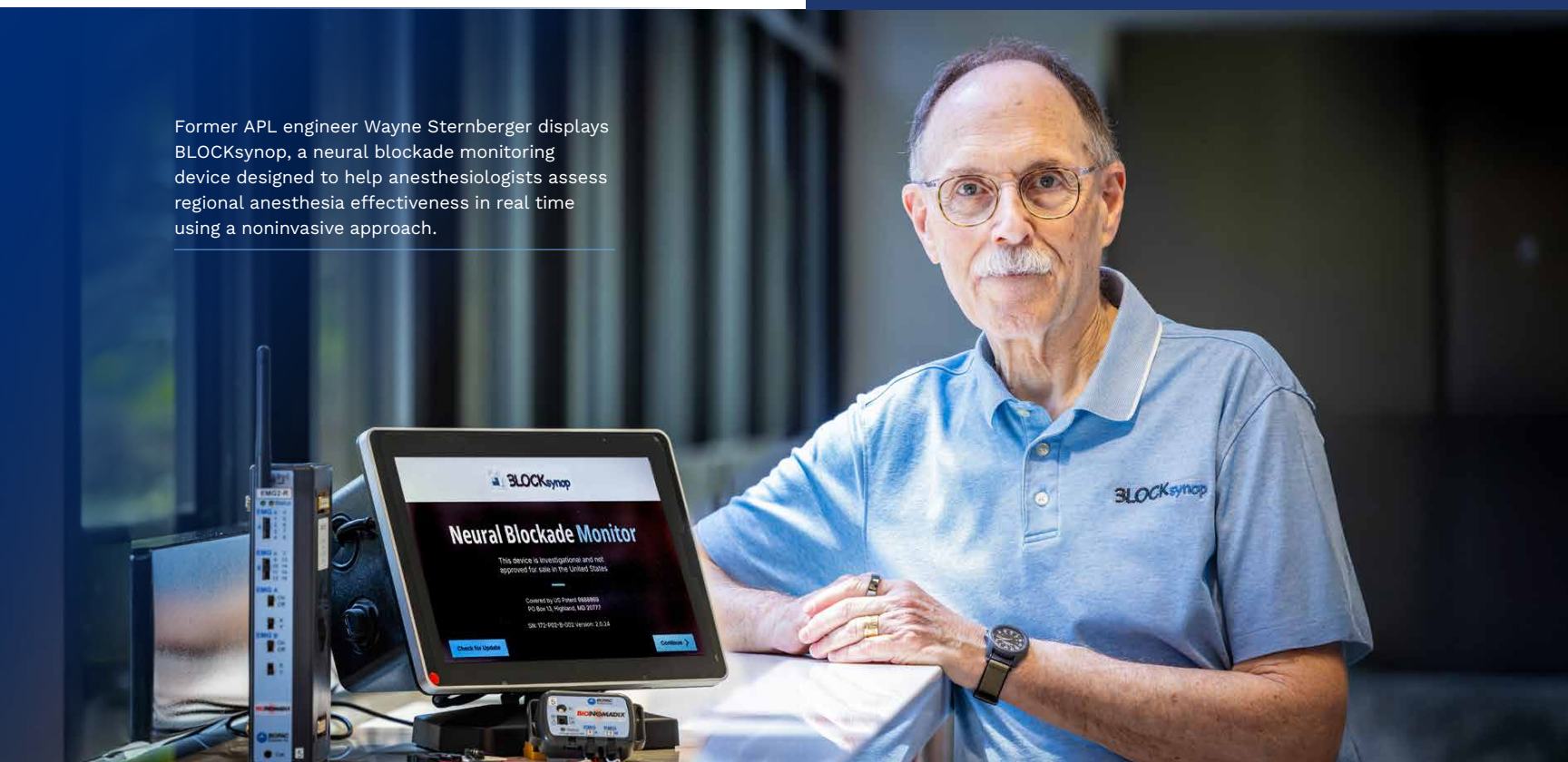
John Sittmann, founder of Deep Root Biolabs, and APL Director David M. Van Wie. Sittmann is the third Archimedes Award recipient and was presented with the award in October 2025.

Program Spotlight: Archimedes Award

Launched in 2019 by APL's Tech Transfer, the Archimedes Award promotes entrepreneurship and accelerates the commercialization of Laboratory technology. Each year, up to two recipients are selected to receive two years of office and lab space at Johns Hopkins Technology Ventures' FastForward innovation hubs, along with a package of medical and other benefits for the same time period. The recipient in 2025 was John Sittmann.



Former APL engineer Wayne Sternberger displays BLOCKsynop, a neural blockade monitoring device designed to help anesthesiologists assess regional anesthesia effectiveness in real time using a noninvasive approach.



UNIVERSITY COLLABORATIONS

APL's strategic collaborations with other Johns Hopkins University (JHU) divisions strengthen the Lab's ability to tackle the nation's most complex technical challenges. Working alongside university researchers, faculty, and students, APL experts transform foundational research into real-world solutions while providing technical and strategic guidance at the intersection of academia, industry, and government. These partnerships leverage the expertise of a world-class research institution to accelerate innovation, educate the current and future workforce, and develop impactful technologies that address national priorities.



The Johns Hopkins Bloomberg Center in Washington, D.C., serves as a hub for collaboration among APL researchers, university faculty, policymakers, and industry leaders, advancing dialogue at the intersection of science, technology, and national priorities.



As part of the Applied Space Strategy Forum, participants tour APL's space facilities and engage with experts on advanced national security space capabilities.

Partnerships With a Purpose

APL collaborates with more than a dozen JHU centers, including the newly formed Data Science & AI Institute, the Hopkins Extreme Materials Institute, and the Information Security Institute, on numerous projects spanning low Earth orbit communications, materials discovery driven by artificial intelligence (AI), extreme-temperature materials that can withstand hypersonic speeds, optical circuit components, brain-computer interfaces, and agentic AI robotics for field casualty care. A flagship example of this partnership is the SURPASS program, where interdisciplinary teams of APL and Whiting School of Engineering (WSE) researchers use innovative, multidisciplinary approaches to address some of the world's most pressing challenges.

The Laboratory also works closely with Johns Hopkins faculty to shape degree programs, certificates, and coursework that support national security goals, often providing secure labs and classified training. For example, APL partners with the Johns Hopkins University School of Advanced International Studies (SAIS) on a graduate-level national security education initiative with the U.S. Space Force that prepares military, interagency, and international professionals for leadership roles in the space domain. Through this collaboration, APL complements SAIS's academic leadership by providing mission-relevant, classified research opportunities in national security space, technology, and strategy, along with access to specialized facilities and applied research environments aligned with real-world operational needs.

In 2025, this partnership expanded with the launch of the Applied Space Strategy Forum, bringing participants to APL multiple times throughout the year for deep dives into cutting-edge, and often classified, technical topics and facilities. The collaboration also enabled direct engagement

with APL research teams, including hands-on participation by a program participant embedded with an APL space systems team, and featured SAIS faculty contributions at the Cislunar Security Conference, underscoring the strength of the integrated academic-technical exchange.

Thought Leadership in the Nation's Capital

In 2025, APL researchers deepened thought leadership with federal and academic partners through a series of workshops and exchanges hosted at the Hopkins Bloomberg Center in Washington, D.C. They joined a workshop on human-machine teaming in space, contributing expertise in autonomous systems and strategy to discussions on the role of synergistic human-robot systems in sustained lunar and deep-space exploration. APL experts also engaged in a technical exchange with faculty from Johns Hopkins' SAIS, offering perspectives on AI's impact on the economy, defense, and national security and advancing a broader dialogue spanning policy, technology, and real-world implementation challenges.

Additionally, APL experts participated in high-profile programming at the Bloomberg Center that infused science, policy, and innovation into the national dialogue. In November, Space Exploration Sector Head Robert D. Braun joined industry leaders on a panel examining cutting-edge technologies shaping the space economy. APL's contributions to interdisciplinary innovation were further highlighted at the inaugural Fast Company World Changing Ideas Summit, where breakthroughs in areas including brain-computer interfaces, planetary defense, and national security space reinforced APL's role in translating research into transformative impact. Lending deep expertise in the cislunar domain, National Security Space Mission Area Executive Dennis Woodfork contributed to the Space Force Association's Spacepower Series: Cislunar Space, sharing applied technical perspectives on emerging space capabilities and operational challenges with senior space professionals and stakeholders on Capitol Hill.



APL experts join academic and industry leaders at the Hopkins Bloomberg Center for a panel discussion on emerging technologies shaping the space economy to contribute perspectives on innovation, policy, and the future of space exploration.



Michael Wolmetz, program manager for the Human and Machine Intelligence Program, speaks at the Fast Company World Changing Ideas Summit about advances in high-resolution, noninvasive brain-computer interface technology and the ways this technology could reshape how humans interact with machines across industries.



Dennis Woodfork, APL's National Security Space Mission Area executive, discusses the emerging opportunities and security challenges of cislunar space at the Fast Company World Changing Ideas Summit.



(From left) Danielle Howe, Alan Ravitz, and Lee Stearns received a 2025 Johns Hopkins Discovery Award for Smart Room Monitoring: AI-Powered 3D Simulation for Multi-Factor Fall Hazard Detection in Health Care Settings, a cross-disciplinary effort that applies artificial intelligence to improve safety in clinical environments.

Discovery Awards

Over the past decade, the Johns Hopkins Discovery Awards have funded high-impact, cross-disciplinary research efforts between JHU collaborators. In 2025, 38 teams, consisting of 142 researchers from 12 JHU entities, received up to \$175,000 each to tackle complex challenges ranging from health care to fundamental physics. Among them were four projects led by APL researchers that focused on developing safer, stronger batteries; creating a multimodal sensing system that uses AI to detect fall, injury, or infection hazards; crafting localized pain-management sutures to curb opioid use; and refining digital cameras to detect dark matter.



A group of systems engineering graduates from APL are pictured at their 2025 spring master's commencement ceremony at the Johns Hopkins University Homewood campus.

Engineering for Professionals

APL collaborates with WSE to lead graduate programs through the Johns Hopkins Engineering for Professionals (EP) program. APL continues to play a critical role in the development of programs for EP, which originated as an in-house program for the advanced training of APL employees.

This year, several APL staff members were selected to chair or cochair Johns Hopkins EP graduate programs. Jason Kalirai, APL's mission area executive for Space Formulation, was named chair of the Applied Physics program, while Zerotti Woods, an expert in intelligence, surveillance, and reconnaissance systems, was appointed cochair of the Data Science program alongside Ben Rodriguez, an experienced data science researcher. Kristin Fretz, managing executive

of APL's Space Exploration Sector, was appointed chair of the Space Systems Engineering program, and Stephanie Caporaletti, a leader in autonomous health technology research, was selected to chair the nationally top-ranked online Engineering Management program. Additionally, APL's Tom Van Doren, Hugh Cameron, Karl Holub, Tim Simpson, and Millie Wears were recognized with EP Faculty Awards for their expertise, leadership, and sustained contributions to the program in 2025.

These leadership appointments and recognitions build on APL's long-standing role in developing and teaching EP programs. The faculty comprises scientists and engineers from APL and WSE; from regional aerospace, engineering, and information technology companies; and from government agencies. Fourteen of EP's 23 programs are based at APL and chaired by APL staff members.

RISE@APL

The RISE@APL program is a prestigious and highly competitive initiative that prepares JHU students majoring in engineering, computer science, applied mathematics, and physics for advanced technical careers. Open to undergraduate and graduate students from WSE and the Krieger School of Arts and Sciences, RISE@APL places participants alongside APL staff members on mission-driven projects spanning multiple Laboratory mission areas. Since its launch in 2014, RISE@APL interns have made meaningful contributions to efforts ranging from ballistic missile systems and computer vision to prosthetics and secure mobile communications.

Fresh Thinking, New Connections: Inside the Lab's Sabbatical Program

APL's Sabbatical Research Program allows staff members to step back into academic life, pairing their deep technical expertise and security focus with university collaborators' academic acumen to fuel ideas and expand the impact of both institutions.

After informal discussions with cardiothoracic surgeons at Johns Hopkins School of Medicine, APL computational physicist Paul Burke applied his multiphase-fluid-dynamics expertise to model pediatric aortic blood flow, a problem far outside his usual defense work. Providing time and funding, the sabbatical allowed Burke to lead the effort, produce the team's first peer-reviewed paper, and attract additional external interest. Burke's experience shows how APL staff can leverage university partnerships to tackle novel challenges, broaden their scientific horizons, and generate breakthroughs that benefit multiple application spaces.

APL computational physicist Paul Burke leveraged a sabbatical collaboration with Johns Hopkins School of Medicine to apply multiphase-fluid-dynamics modeling to pediatric aortic blood flow, expanding his research beyond traditional defense applications and contributing to advances in biomedical science.



AWARDS AND HONORS



1. For the seventh year in a row, APL was named to Fast Company's list of the Best Workplaces for Innovators. APL placed 50th on this year's list of the 100 most innovative organizations from around the world, selected from nearly 1,000 applicants. This is APL's seventh straight placement in the Top 50, making the Laboratory the only organization to achieve this feat since the award's inception in 2019, and one of only two companies to have been named to the list every year.

2. For the eighth consecutive year, APL was placed by Foundry's Computerworld on its list of Best Places to Work in IT, which recognizes the top worldwide workplaces for information technology professionals. The Laboratory was ranked No. 41 overall among large organizations.

3. A next-generation thermoelectric refrigeration technology developed by APL researchers was named a winner in the 2025 R&D 100 Awards and was recognized as one of the 100 most innovative emerging technologies in research and development. The refrigerator system runs on APL's controlled hierarchically engineered superlattice structures (CHES) — nano-engineered thermoelectric materials that transfer heat with significantly high efficiency. This breakthrough nearly doubles the performance of traditional materials at room temperature, paving the way for much better cooling systems and energy-saving technologies.

4. Kostas Gerasopoulos (left) and Robert Osiander (right) are APL's newest Master Inventors — a select group of Laboratory staff members cele-

brated for securing patents based on APL intellectual property and careers focused on innovation.

5. The National Aeronautic Association awarded the innovative team of engineers and scientists from NASA, APL, and more than 40 other partner organizations across the country that created the revolutionary Parker Solar Probe with the 2024 Robert J. Collier Trophy. This prestigious award recognizes the most exceptional achievement in aeronautics and astronautics in America with respect to improving the performance, efficiency, and safety of air or space vehicles in the previous year. Shown here are mission team members during the June 12, 2025, ceremony in Washington, D.C. Credit: National Aeronautic Association

6. APL's Ashutosh Dutta was inducted into the New Internet Protocol version 6 Hall of Fame, a nod to his leadership promoting the next-generation protocol that expands internet access and improves operation and security.

7. Paul Kennedy, an engineer who leads APL's electronic warfare signal processing team, was awarded the Association of Old Crows' Future 5 award for his professional contributions in developing electronic warfare capabilities for APL's Department of War sponsors. The award recognizes young professionals for their innovation and excellence. Credit: David Keith Photography

8. David M. Van Wie, APL director and former head of the Laboratory's Air and Missile Defense Sector, received the inaugural Kevin C. Greenough Award from the University of Maryland A. James Clark School of Engineering. Credit: University of Maryland/Mike Morgan

9. For the fourth consecutive year, APL was honored with a Glassdoor Employees' Choice Award as one of the top 100 Best Places to Work among large U.S. companies. The award is based entirely on voluntary, anonymous employee reviews of their work environments. This year, APL ranked 34th on the list, marking its fourth year in a row as a top-50 selection from among the more than 10,000 large companies tracked by Glassdoor. As in 2023 and 2024, the Lab was the top-ranked defense and space organization.

10. Jason Kalirai, an astrophysicist and mission area executive for Space Formulation, was selected as a fellow by the American Astronomical Society. The society credited him "for taking a holistic approach to astronomical sciences by leveraging ground- and space-based telescopes to place novel constraints on astrophysical mass functions; for expertly leading and enabling new space missions including DART and Dragonfly; and for bold advocacy for astronomy and inspiring the next generation."

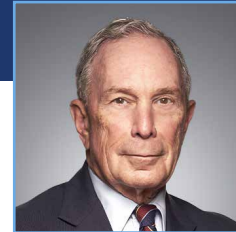
BOARD OF MANAGERS



Heather H. Miller
Chair, APL Board of Managers;
Private Investor; Cofounder,
Nevada Cancer Institute;
JHU Trustee



Jeffrey S. Barber
Head of TA Associates' North
America Consumer Group;
Chair, Dean's Advisory Board,
JHU Krieger School of Arts
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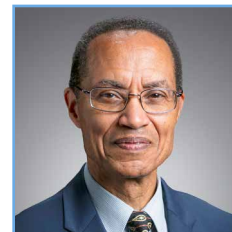
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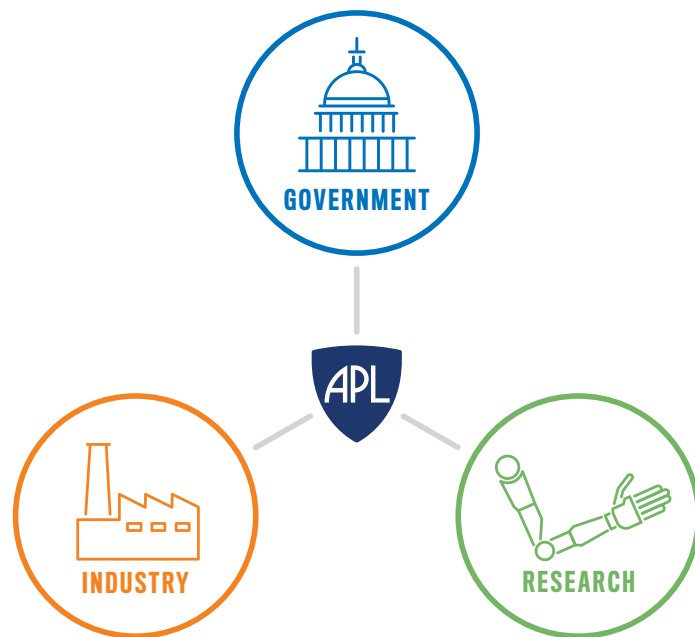


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— Department of War UARC Engagement Guide



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- Comprehensive knowledge of sponsor requirements and problems
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