THE JOHNS HOPKINS APPLIED PHYSICS LABORATORY

2020 ANNUAL REPORT

CRITICAL CONTRIBUTIONS TO CRITICAL CHALLENGES

CONTENTS

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— RALPH SEMMEL, Director

DIRECTOR'S MESSAGE

In my decade as the director of the Johns Hopkins Applied Physics Laboratory, I have never been prouder of my colleagues than I was during 2020.

The talented engineers, scientists, researchers, administrative professional and support staff members of APL have tackled the nation's toughest technical problems for nearly 80 years. But this was a year like no other, requiring us to apply our skills and talents in creative, innovative and unprecedented ways.

Faced with the lingering and year-defining COVID-19 pandemic, our sponsors and the nation counted on APL to make critical contributions to their critical challenges. We adapted — and often invented — a "new normal" that allowed us to work both on-site and from home in support of our mission. As Laboratory staff have throughout our history, we responded — delivering breakthrough technologies and game-changing solutions to strengthen national security and advance the frontiers of science.

Our resilience is evident on the pages of this annual report. We engaged directly in the nation's battle against COVID-19, leveraging expertise in specialties from data analytics and genomics to disease surveillance and artificial intelligence, and teaming with partners from across Johns Hopkins. We delivered groundbreaking, innovative technologies to warfighters that strengthened the nation's air, sea and cyber defenses. We tapped the depth and breadth of our interdisciplinary, cutting-edge research to push the boundaries of the possible in areas from hypersonics to quantum computing to prosthetics; delivered hardware and expertise to space missions that will expand our knowledge of the solar system; and mapped a comprehensive strategy to ensure the Laboratory will continue to deliver critical contributions in a post-pandemic world.

The adaptations required to meet these challenges over the past year — whether wearing masks in specialized laboratories, building unique technologies in cleanrooms, or brainstorming in offices and on video calls — attested to the strong relationships APL staff members have with our sponsors and, most important, with one another.

There were other challenges facing our nation this year. Around the U.S., public outcry over violent acts forced the nation to reckon with the enduring effects of racial injustice. These self-assessments reinforced for us the idea that diversity and inclusion is a strategic necessity, and that ensuring a workplace where everyone can contribute and thrive is critical to our ability to innovate in the face of increasingly complex problems.

I will not forget how this year showed me the best of what APL has to offer: a true team, nearly 8,000 strong, that met the demands of an extraordinary time with resolve, perseverance and compassion.

Many times over the past decade, I have encouraged the people of APL to be bold, do great things and make the world a better place. As you read through this annual report, I am sure that you will see that is exactly what they have been doing.

Ralph Semmel

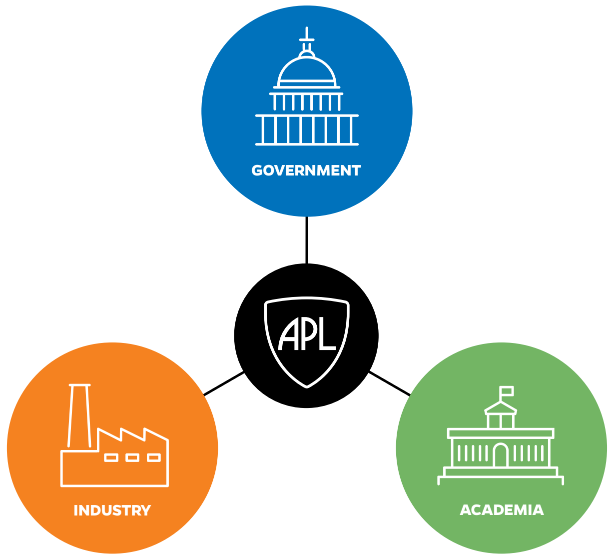
APL: A UNIVERSITY AFFILIATED RESEARCH CENTER

University affiliated research centers (UARCs) are independent, nonprofit organizations that conduct essential research, development and systems engineering to strengthen our nation. The centers focus on strategic national priorities, free from conflicts of interest or competition with commercial industry. They provide the U.S. government with access to highly skilled scientists, engineers and analysts to tackle vital national security and scientific challenges.

ABOUT UARCS

"[UARCs] are not-for-profit entities sponsored and primarily funded by the U.S. government to address technical needs that cannot be met as effectively by existing government or contractor resources. These organizations typically assist government agencies with scientific research and development, studies and analyses, and systems engineering and integration by bringing together the expertise of government, industry, and academia to solve complex technical problems in the public interest."

—Department of Defense UARC Engagement Guide



OUR LONG-TERM STRATEGIC RELATIONSHIPS WITH SPONSORS ARE CHARACTERIZED BY:

- Responsiveness to evolving sponsor requirements
- Comprehensive knowledge of sponsor requirements and problems
- Broad access to information, including proprietary data
- Broad corporate knowledge
- Independence and objectivity
- Quick response capability
- Current operational experience
- Freedom from real or perceived conflicts of interest

AS A UARC, APL IS A DIVISION OF JOHNS HOPKINS UNIVERSITY.

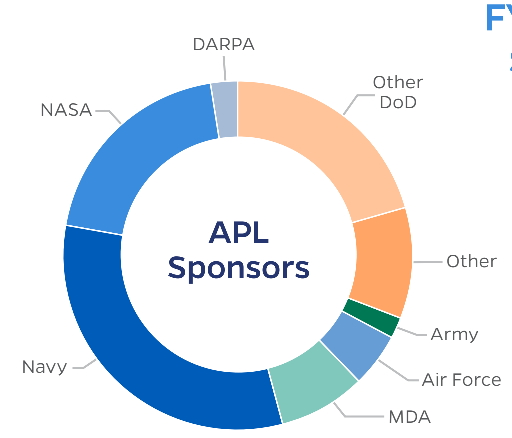
This is a relationship we hold dear and one that helps to enable our objective and independent work.

While we have strict conflict-of-interest restrictions, our sponsors can include government offices and philanthropic organizations.

UARCs function broadly as trusted technical experts, often developing advanced systems prototypes that accelerate the infusion of new technology into operational use. When appropriate, and where no conflict of interest exists, they may compete for science and technology work on Broad Agency Announcements and Announcements of Opportunity.

The majority of our work comes from the Department of Defense as sole-source (noncompetitive) funding under the Competition in Contracts Act, primarily through the exception for essential research and engineering.

ABOUT APL



FY20 Revenue: $1.85 Billion

APL'S MISSION IS TO MAKE CRITICAL CONTRIBUTIONS TO CRITICAL CHALLENGES.

Our success as a UARC depends on:

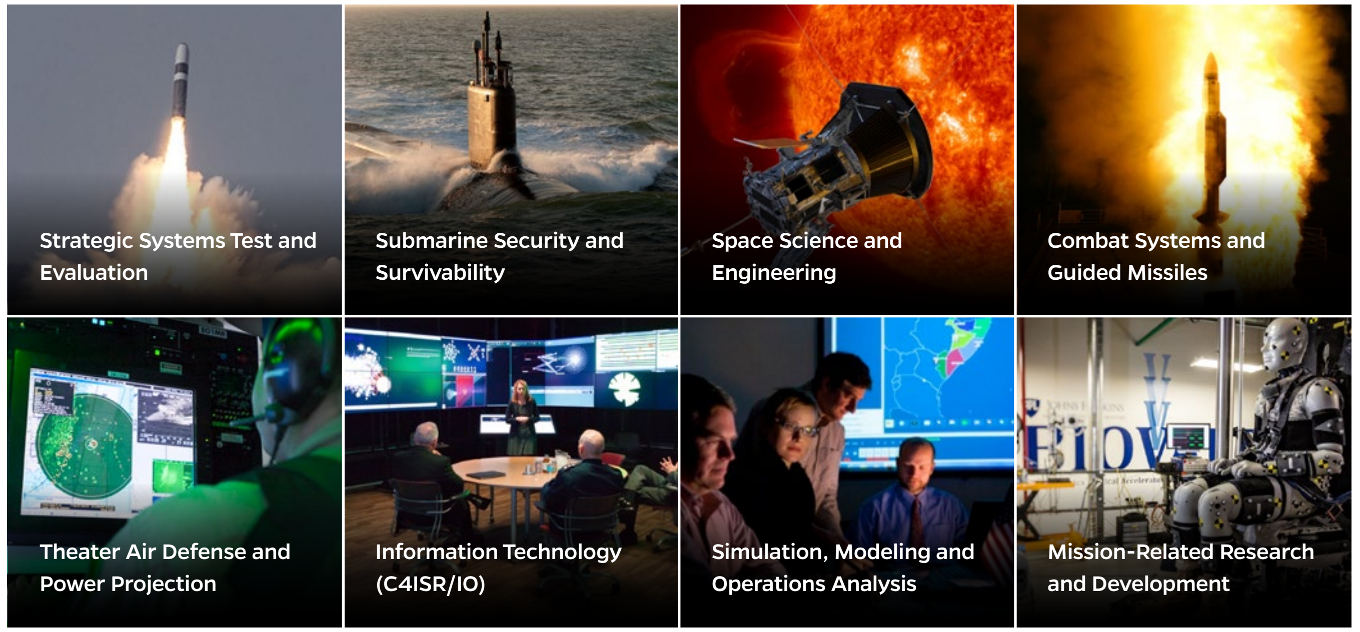
- Broad exposure to challenges facing a wide variety of sponsors
- A diversity and depth of expertise and experience to address those challenges
- Our track record of bringing together government, academia and industry to solve complex challenges

OUR ACCESS TO NUMEROUS INNOVATION ECOSYSTEMS HELPS US IN OUR WORK.

In 2020, we had:

- 115 different government sponsors
- 118 subcontracts to 45 different universities

APL CORE COMPETENCIES



INNOVATION

AND IMPACT DURING CHALLENGING TIMES

Rooted in our core values — unquestionable integrity, trusted service, world-class expertise, game-changing impact and a collaborative, fulfilling environment — APL staff members met the unprecedented demands of 2020 with unwavering dedication and ingenuity.

Johns Hopkins APL joined the Johns Hopkins University COVID-19 dashboard effort on Jan. 27, 2020. Within months, the tool became the most trusted, accurate source of information available on the pandemic, and the data source relied upon globally for near-real-time tracking of the biggest health crisis this century.

For nearly eight decades, the men and women of the Johns Hopkins Applied Physics Laboratory have rallied around challenges and boldly embraced change in the name of national security and space exploration. Rooted in our core values — unquestionable integrity, trusted service, world-class expertise, game-changing impact and a collaborative, fulfilling environment — APL staff members met the unprecedented demands of 2020 with unwavering dedication and ingenuity.

The emergence and spread of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the virus responsible for the current coronavirus pandemic (COVID-19), presented complex new challenges for the United States and the world — and for APL research teams.

Assistant Director Christine Fox (left) discusses the COVID-19 pandemic with Gen. Mark A. Milley, chairman of the Joint Chiefs of Staff, during a briefing with experts from APL and the Johns Hopkins Bloomberg School of Public Health. (Credit: Department of Defense)

Chief of Staff of the U.S. Air Force Gen. David L. Goldfein was briefed on COVID-19 research and data findings during a late May visit to the Laboratory.

Through the crisis, the Laboratory remained open for business, continuing to answer the call to help solve the nation's most pressing issues, all while ensuring the safety of our staff and continued operations whether at home, in our classified spaces or in our highly specialized laboratories. The need for critical contributions in 2020, across all domains, was as great as ever, if not more so.

Staff members joined the nation's battle against COVID-19, leveraging expertise in artificial intelligence (AI), disease surveillance, rapid prototyping, modeling and simulation, genomics, experimental characterization and, of course, systems engineering. Their collaborations spanned the Laboratory, Johns Hopkins University and Medicine (including our data acquisition and analysis for the renowned Johns Hopkins Coronavirus Resource Center), the nation and the globe.

The Lab's expertise in operations analysis and predictive modeling drew attention from the highest levels of government. Dozens of APL staff members spent much of 2020 supporting the National COVID-19 Response, initially under the Federal Emergency Management Agency (FEMA). The APL team worked around the clock to advise leaders across government on its response to COVID-19.

Beyond APL's support for the national COVID-19 response, APL has served as a key resource throughout the pandemic. Gen. Mark A. Milley, the chairman of the Joint Chiefs of Staff, huddled with senior advisors and APL experts in the Lab's Collaborative Analysis Center for deep discussions on combating the pandemic's effect on our nation's military readiness.

Despite the new needs of the nation and the challenge of operating in a pandemic, our staff members continued and completed the critical work of national security. We developed and delivered a critical software update for the Aegis Combat System, for which APL has served as technical advisor or technical direction agent since 1974 (page 14). We advanced research in hypersonic flight (page 16). We supported the evolution of cyber defenses for state and local governments (page 23). We developed advanced materials for everything from spaceflight to warfighter protection (page 15). We tapped radio-frequency emitters and video-game engines to take airport scanners to new levels of accuracy and efficiency (page 24).

Through the crisis, the Laboratory remained open for business, continuing to answer the call to help solve the nation's most pressing issues, all while ensuring the safety of our staff and continued operations whether at home, in our classified spaces or in our highly specialized laboratories.

Page 9: Top left (Credit: U.S. Navy), top right (Credit: Missile Defense Agency).

OUR DEDICATION

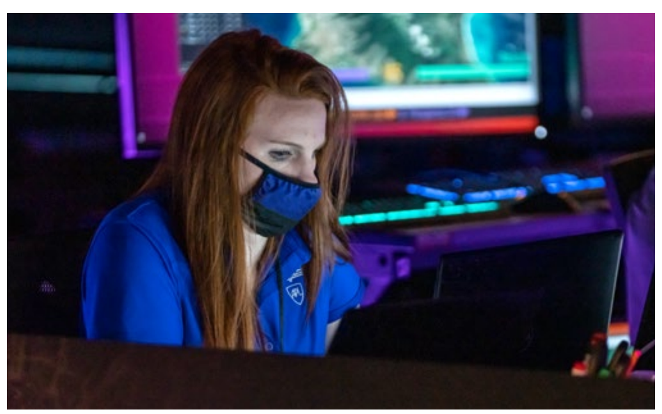
APL never ceased operations in 2020, and thousands of our staff members continued to work on-site throughout the pandemic, focused on fulfilling our mission and supporting crucial programs while protecting teams engaged in on-site work.

While the Laboratory adopted remote work to the maximum extent possible, staff members supporting ongoing challenges such as space missions, including Joshua Albers (left) and John Murdock, modified their routines and took extra precautions to continue their critical work.

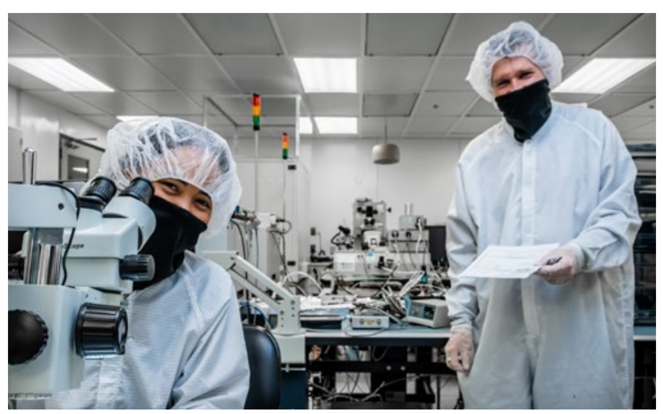
Our teams modified work schedules and took extra safety precautions to tackle assembly and testing of our NASA missions and instruments — including the APL-built Double Asteroid Redirection Test (DART) spacecraft, scheduled to launch in late 2021. We also delivered instruments and major components of the Europa Clipper spacecraft (launching in 2024), as well as cameras and spectrometers for the Lucy (2021) and Psyche (2022) missions. In a first for APL, staff members executed a virtual proposal review with NASA, leading to the awarding of the Electrojet Zeeman Imaging Explorer (EZIE) mission as one of its next space physics explorations, due to launch no sooner than 2024.

Supporting this work against the backdrop of the changing understanding of the virus as well as evolving safety guidelines took around-the-clock work by the Laboratory's Environmental Health and Safety Group. APL never ceased operations in 2020, and thousands of our staff members continued to work on-site throughout the pandemic, focused on fulfilling our mission and supporting crucial programs while protecting teams engaged in on-site work. The Lab based all its operational decisions over the year on seven precepts: health and safety, our mission, flexibility, financial viability of the institution, strategic impacts, and compassion and fairness for all.

In a year of challenges and threats that spanned unparalleled domains, the Laboratory and its dedicated people showed bravery, ingenuity, dedication and compassion again and again to safely deliver foundational research and cutting-edge innovations. We have always been proud of our staff and our accomplishments, and we knew that this adversity would only strengthen our resolve and our commitment to delivering for our sponsors, our teammates and our nation.



Kelly Brady and her colleagues worked to deliver the technical criteria and framework for the 2020 AlphaDogfight Trials, a competition between AI research teams that culminated in simulated dogfights between a human pilot and AI.



Vanessa Rojas (left) and John Lehtonen at work in APL's microelectronics facility, which was updated to minimize the impact of COVID-19 and increase an already-high level of cleanliness. This included an improved layout, new protocols and the implementation of occupancy limitations.

BOLD

RESEARCH ADVANCES

At APL, we create technologies and innovations to protect our homeland and warfighters, enable teamwork between people and machines, expand the limits of computing power and improve the ability of people to survive in the most remote parts of the globe. By combining creativity and technical expertise with a culture of risk-taking — brought together in cutting-edge collaboration spaces, labs and test facilities across our campuses — we tackle increasingly difficult challenges with impacts across multiple domains.

APL served as a core member of the Air Combat Evolution program team created by the Defense Advanced Research Projects Agency (DARPA) for the 2020 AlphaDogfight Trials, a showdown between eight AI research teams from across the United States. In the final, the winning AI agent went 5–0 against real-life U.S. Air Force F-16 pilot "Banger," shown here.

“This flight test mission success, which demonstrates the robustness of the Aegis BMD combat system and the SM-3 Block IIA missile, exemplifies the continued partnership between APL, the Missile Defense Agency and industry.”

— BARBARA LAKOTA, APL Aegis BMD Program Area Manager

DEFENSE IN LAYERS

As technical direction agent for the Aegis Ballistic Missile Defense (BMD) system, APL investigates the toughest strategic and technical problems for the Missile Defense Agency (MDA). Our latest challenge was to answer this question: Could a Navy ship equipped with the latest Standard Missile-3 (SM-3) engage and defeat an incoming intercontinental ballistic missile. The answer would determine Aegis BMD’s feasibility as part of a nation’s layered air and missile homeland defense system.

APL applied its range of technical and analytical talents to uncover that answer, which was a resounding yes. Lab experts were central to a successful and historic MDA-led demonstration in fall 2020, during which an SM-3 Block IIA missile intercepted and destroyed a target representing an ICBM.

A year before the flight test, APL engineers and scientists began conducting analyses, risk assessments and experiments in areas critical to the demonstration. They also developed prototypes to prove concepts in high-risk technological areas, structuring a test to demonstrate the robustness of the Aegis BMD combat system and the SM-3 Block IIA missile, as well as the system’s ability to meet a challenge essential to national security.

With the plans in place and all systems “go,” sailors aboard the USS John Finn (DDG-113), using the Command and Control, Battle Management and Communications (C2BMC) network, tracked the target via remote radar and then launched the SM-3 Block IIA guided missile toward the target — and destroyed it. As Lab experts quickly began evaluating system performance using data obtained during the test, one thing was already clear: this accomplishment was a pivotal milestone for the Aegis program, affirming another effective collaboration between MDA, APL and industry as well as showcasing APL’s deep knowledge of the nation’s critical missile defense systems.

An SM-3 Block IIA is launched from the USS John Finn, an Aegis Ballistic Missile Defense system-equipped destroyer, as part of Flight Test Aegis Weapons System-44 (FTM-44) on Nov. 16. FTM-44 was a developmental test to evaluate the feasibility of the missile’s capability to defeat an intercontinental ballistic missile threat. (Credit: Missile Defense Agency)

TEAMING HUMANS AND MACHINES

To meet the challenges of our adversaries, such as hypersonic weapons, the Laboratory continued its pursuit of unmanned and intelligent systems that are optimally partnered with human decision makers. That partnership is founded on human trust in these new systems, a domain where APL is leading the development of technology and processes to both build assured autonomy and appropriately test it.

As a core member of the Air Combat Evolution (ACE) program team created by the Defense Advanced Research Projects Agency (DARPA), APL developed the technical criteria and framework for the 2020 AlphaDogfight Trials, a showdown between eight AI research teams from across the United States. We leveraged our capabilities in artificial intelligence (AI) and software development, modeling and simulation, and aircraft dynamics and controls to create the virtual environment for this novel competition — in which the teams flew their AI algorithms against five APL-developed computer adversaries. Our algorithms allowed the teams to train their AI agents against constantly updated adversaries, to the point where one team’s virtual agent bested a human pilot in the competition finals.

The lasting effect of the computer “win” is the promise of effective, trusted future airborne combat systems and concepts involving human-machine teaming. APL has also created a strong foundation for further algorithm development in the ACE program as it moves from simulations to testing algorithms and measuring pilot trust on an actual aircraft.

DARPA’s Lt. Col. Justin “Glock” Mock (left) and APL’s Chris “Disco” DeMay, program manager for the DARPA ACE program at the Lab, served as cohosts throughout the three-day AlphaDogfight Trials.

EXTRACTING WATER FROM AIR

APL researchers have marshalled their collective expertise in materials and chemistry to have an impact. Laboratory scientists and engineers are inventing the future of clean drinking water for deployed warfighters and, potentially, individuals around the world by successfully testing highly absorbent materials that can extract drinkable water from the air.

The work leverages metal–organic frameworks (MOFs), sponge-like crystals that can be used to capture, store and release chemical compounds like water. Just a single gram of the MOF can soak up a football field’s worth of material, if the material were laid in a single layer across the field.

With a kilogram of MOF, APL researchers demonstrated the possibility of producing almost nine liters of water per day — enough to hydrate operators in extreme environments. This notable accomplishment not only helps scientists deepen their understanding of these incredible materials but is guiding the discovery of next-generation water-harvesting methods for use in the most arid areas of the planet.

The range of research fields and challenges that APL is able to explore with its subject-matter experts — and the exciting breakthroughs we can generate in specific areas as well as with multidisciplinary teams — is part of what makes the Laboratory a unique and valuable resource for the nation.

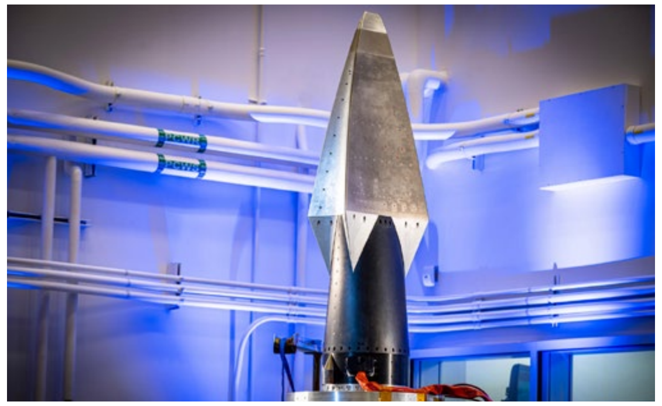
APL’s (from left) Zhiyong Xia, Matthew Logan and Spencer Langevin have identified highly absorbent materials that can extract drinkable water out of thin air — which could potentially lead to technologies that supply potable water in the driest areas on the planet.

EXPANDING HYPERSONIC CAPABILITIES

Hypersonics will be an essential technology in tomorrow's strategic defense landscape, a critical difference-maker in our nation's ability to protect itself and our allies against a new generation of threats. Hypersonic vehicles can reach speeds exceeding 4,000 miles per hour — fast enough to reach Baltimore from Washington in about 30 seconds — and aggressors equipped with hypersonic missiles can penetrate air defenses.

The nation's adversaries are currently testing military applications of hypersonics technology, which adds urgency to APL's ongoing foundational work in hypersonic technologies, work that dates back decades. Leading our efforts in the field this past year was research into predicting the state of the so-called boundary layer — the thin layer of air that moves near the surface of these incredibly fast objects — which is information essential to designing hypersonic vehicles.

The Laboratory has forged partnerships with other top research institutions to tap the full potential of government, industry and academic collaboration. Through an agreement with Purdue University's Institute for Global Security and Defense Innovation that will enhance both institutions' national contributions in this critical field, APL staff members will have access to Purdue expertise and use of its Boeing/Air Force Office of Scientific Research Mach-6 Quiet Tunnel facility, one of the world's largest. Our subject-matter experts will work with Purdue faculty and students in APL's laboratories and additive manufacturing hub to build on the results of the boundary-layer tests and gain insight into materials able to meet the aerodynamic demands of hypersonic speeds.



An APL team developed and built the Boundary Layer Transition (BOLT) flight hardware with help from an Air Force research grant. (Credit: Air Force Office of Scientific Research/Johns Hopkins APL)

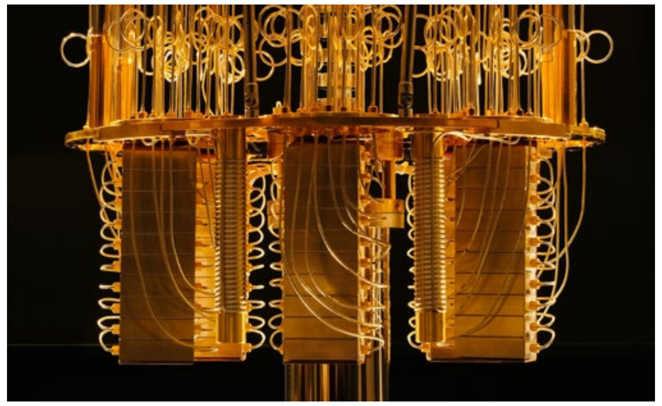
QUANTUM CONTROL

Quantum computing is touted as a paradigm-shifting technology, a new way of processing information that is able to tackle challenges from cryptography to modeling complex systems to developing innovative medicines and materials for extreme environments. But these devices' sensitivity to electrical, magnetic and thermal "noise" renders today's fledgling quantum systems error-prone or, at worst, useless.

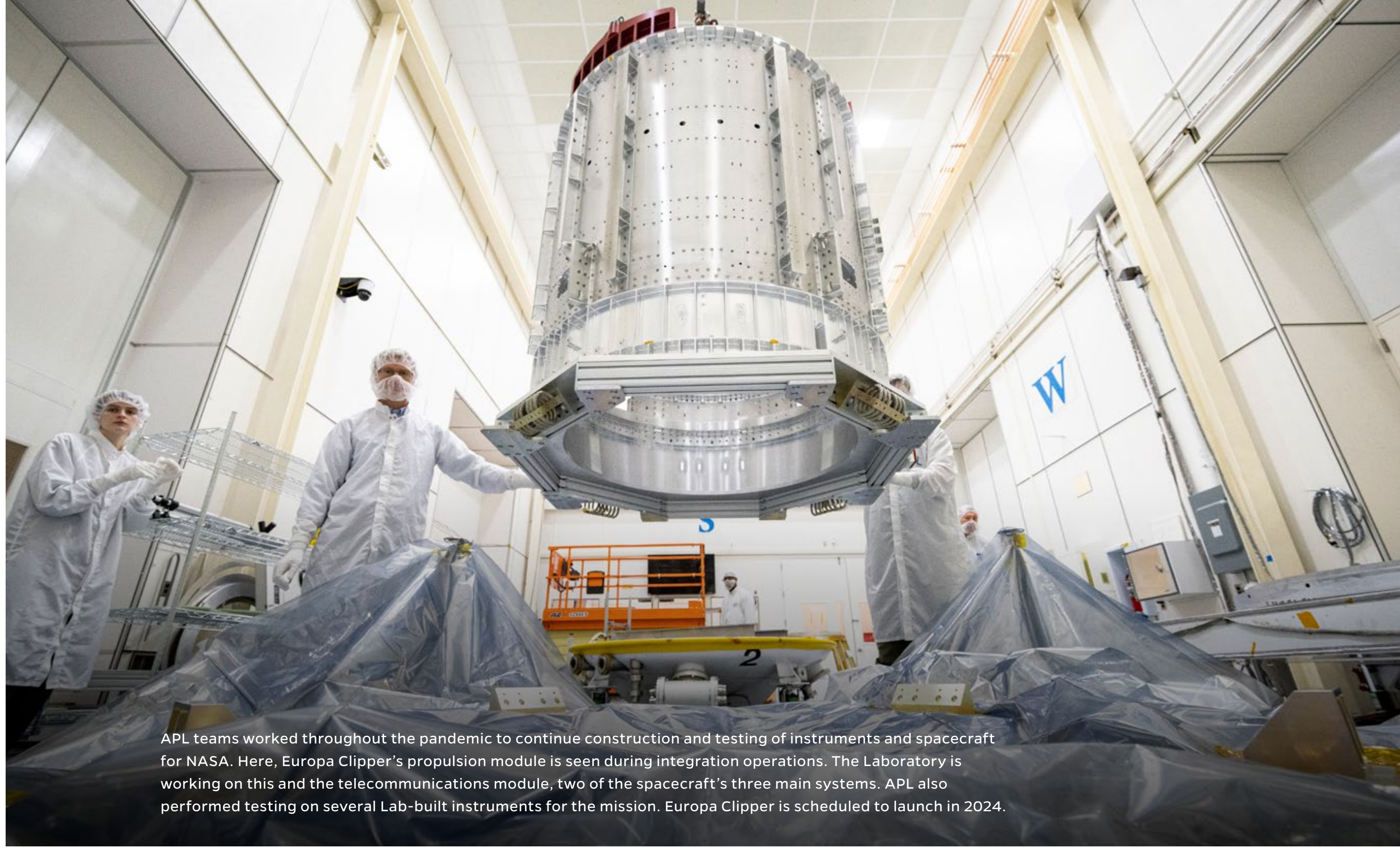
APL researchers and engineers are looking to overcome these hurdles — and push quantum computing closer to realizing its potential — by relaying concepts from control theory, which uses a series of feedbacks to regulate or correct a system and suppress unwanted interactions that intrude from the environment. By adding such control protocols to quantum systems, researchers can make them less "noisy" and thus more accurate, a detail that has attracted renewed attention to the field of quantum control.

Experimenting with small numbers of qubits — the fundamental "bit" of information in quantum computing — along with theory application and modeling, APL researchers are taking steps toward developing tools that can boost the effectiveness of large quantum processors as they become available.

The Laboratory also joined forces with a consortium of scientists and engineers from academia, national laboratories and industry to form the Mid-Atlantic Quantum Alliance, which aims to develop pioneering quantum technology and the next generation of quantum researchers, while working with companies to transition quantum technology for wider use.



Current quantum computers, as shown above, suffer from noise that can render them error-prone and potentially completely useless. APL researchers are developing the control protocols to help curb that noise and make these computers more accurate. (Credit: IBM Research)



APL teams worked throughout the pandemic to continue construction and testing of instruments and spacecraft for NASA. Here, Europa Clipper's propulsion module is seen during integration operations. The Laboratory is working on this and the telecommunications module, two of the spacecraft's three main systems. APL also performed testing on several Lab-built instruments for the mission. Europa Clipper is scheduled to launch in 2024.

BREAKTHROUGH SPACE SCIENCE AND NEW SOLAR SYSTEM EXPLORATIONS

The first mission to fly through the Sun's corona, NASA's Parker Solar Probe, was launched in 2018. Since then, the APL-designed and -built spacecraft has been collecting data from intense heat and radiation regions around our star that were previously inaccessible, thanks to the mission's revolutionary heat shield and thermal management system. Findings from the mission have already changed our understanding of the Sun, solar processes, and how our star and Earth interact.

After data from Parker Solar Probe indicated that the solar wind and related phenomena were occurring much farther from the Sun than previously thought, the spacecraft began its longest science observation campaign in May, in which it would continuously operate its instruments for nearly two months. On Sept. 27, Parker Solar Probe completed its sixth perihelion, or closest approach to the Sun. The spacecraft flew within 8.4 million miles of the Sun's surface, traveling at a speed of 289,927 miles per hour — breaking its own record as the fastest human-built object in the solar system.

Back on Earth, the Laboratory continued to achieve milestones on Europa Clipper, a NASA flagship mission to explore Jupiter's intriguing moon that APL is developing in partnership with the Jet Propulsion Laboratory. Our scientists and engineers worked throughout the pandemic to construct and test Europa Clipper's propulsion and telecommunications modules, two of the spacecraft's three main systems. The Laboratory is also completing testing on several APL-built instruments for the mission, including cameras that will capture parts of Europa in unprecedented resolution and provide 3D images of the surface, as well as a charged particle detector, a magnetometer and a spectrometer that will map the frozen elements on Europa's icy crust. Europa Clipper is scheduled to launch in 2024.

In January, APL began work on another first-of-its-kind exploration mission: NASA's Interstellar Mapping and Acceleration Probe, or IMAP. IMAP will answer fundamental questions about the local interstellar region, the boundaries that surround our solar system (known as the heliosphere) and how particles are accelerated to high energies in space. The mission's 10 instruments will study how cosmic rays are filtered by the heliosphere. These particles pose risks to astronauts and technological systems, but they may also play a role in the formation and presence of life in the universe. The Laboratory will design, build and operate this mission, which is scheduled for a 2025 launch.

DEDICATED

TO THE DEFENSE OF THE NATION

Since its founding in 1942, the Laboratory has proudly served a special role for the United States as a cornerstone research and analysis institution for some of our most critical defense technologies. Since our inception, threats to our national security have emerged, evolved and even sometimes resurfaced after years of dormancy. As they do, our methods to counter these pressing threats have also changed, no matter the operational environment.

To meet these changing challenges, APL calls upon its deep expertise in a number of technical domains, both cutting-edge and foundational, across the nearly 8,000 staff members employed at the Lab.

A target missile launches during a 2019 test from the Ronald Reagan Ballistic Missile Defense Test Site on Kwajalein Atoll in the Republic of the Marshall Islands. A minute apart from each other, two ground-based interceptors were launched from Vandenberg Air Force Base, California. The first intercepted the target, and the second hit a large chunk of the debris. (Credit: Missile Defense Agency)

"As the Technical Direction Agent, we can provide a strong analytical underpinning to the requirements and provide recommendations for addressing some of the most pressing technical challenges facing the Ground-based Midcourse Defense system."

— **JEFF COOLEY, APL Program Area Manager**

One of the two ground-based interceptors launched from Vandenberg Air Force Base, California, on March 25, 2019, in the first-ever salvo engagement test of a threat-representative intercontinental ballistic missile target. (Credit: Missile Defense Agency)

NEW DEFENSES AGAINST BALLISTIC MISSILE THREATS

In 2020, continuing the Laboratory's historical role as a trusted agent to the government, APL became the technical direction agent (TDA) lead for the Missile Defense Agency's (MDA) Ground-based Midcourse Defense (GMD) program, which provides the capability to engage and destroy intermediate- and long-range ballistic missile threats in space.

The TDA acts as a key technical advisor for the government, providing technical expertise to conduct analyses, risk assessments and critical experiments in key areas. It also performs experimentation and develops prototypes to demonstrate proof of concept in areas of high technological risk. The transition in 2020 for APL to lead the current partnership of nine federally funded research and development centers and university affiliated research centers established the Laboratory as the accountable head of the GMD TDA organization, providing unique expertise across all areas of GMD development, including testing and fielding of current and future capabilities of homeland defense.

In this latest role, APL will continue to leverage its decades-long track record as TDA for several other prominent air and missile defense programs, including Standard Missile and Aegis Ballistic Missile Defense. The Laboratory's previous experiences and breadth of competencies across all departments and sectors will be essential to contributing to the design and fielding of the GMD program's Next Generation Interceptor (NGI), an advanced interceptor designed to protect the nation against intercontinental ballistic missile attack. The NGI, which MDA expects will be capable of defeating projected threat advances into the 2030s and later, will replace the current ground-based interceptors and serve as the nation's first line of defense.

APL serves as the technical direction agent lead for the Ground-based Midcourse Defense element of the nation's ballistic missile defense system. Successful tests to date include the interception of this intercontinental ballistic missile-class target, launched from the Ronald Reagan Test Site on Kwajalein Atoll. (Credit: Missile Defense Agency)

SEEING THE UNSEEN WITH DARC

While the Lab's heritage is in air and missile defense, our history and knowledge of space science and engineering is also a core competency. Among many space-related programs at the Laboratory are the projects that focus on locating and following satellites in geosynchronous orbit. This task is challenging for optical sensors in space and on the ground, which are hampered by sunlight and weather as well as range and sensitivity limitations that fail to achieve the precision required for these objects.

The Laboratory is leading solutions for the Space Force with the Deep Space Advanced Radar Concept (DARC) technology demonstrator program. Using a minimum of just three ground-based antenna sites, spaced at mid-latitudes around the world, the government plans to operationalize the ability to detect, track and maintain awareness of satellites in, to and through geosynchronous orbit.

The test and demonstration efforts reduced the technical risk and validated the system design before the implementation of an operational radar system. With the technology demonstrations complete, the Space Force has moved to procure a full system from industry incorporating the lessons learned from APL's design — giving the nation a constant capability to track potential threats to missile warning, communications and other national security satellites.

"The Deep Space Advanced Radar Concept technology demonstration program is retiring a number of risks for a future operational radar that enables deep space domain awareness for the nation."

— **DONNA BUSH, APL DARC Program Manager**

APL is developing solutions for the U.S. Space Force and the tracking of adversary satellites with the Deep Space Advanced Radar Concept demonstrator program, which includes prototype antennas shown here at White Sands Missile Range, New Mexico. (Credit: White Sands Missile Range)

Cerberus project team members (from left) Lynn Reggia, Joel Jorgensen, Matthew Burton, Jackie Hatleberg, Howard Eaton, Derrick Treichler and Travis Heslop discuss the latest designs and updates for the APL-developed next-generation mission planning prototype, which will advance the state of the current Integrated Air and Missile Defense force-level mission planning and fill the gaps in ballistic missile defense identified by warfighters.

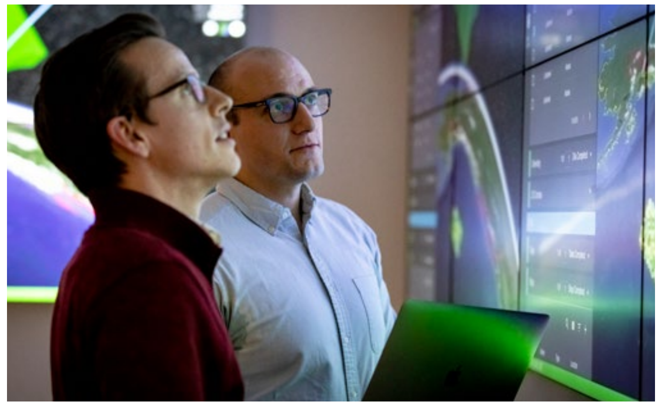
FASTER, BETTER MISSILE DEFENSE PLANNING

Just as tracking adversary satellites requires a suite of technologies working together, defending against ballistic missiles requires the harmony of diverse sensors, weapons and platforms operating across great distances. Achieving that harmony requires situational awareness by unit commanders and the proper positioning of sensor and shooter platforms relative to the threat and to each other.

To accomplish this positioning, APL successfully developed a rapid prototype of an advanced, next-generation mission planning tool, called Cerberus. Developed for the Missile Defense Agency (MDA), the prototype — which APL delivered in just 12 months — rapidly provides the warfighter with ship placement and combat system configuration options to successfully carry out planning for the ballistic missile defense mission.

In 2020, a year after MDA challenged the Laboratory's team to evolve Cerberus' capabilities even further, the team overcame the difficulties of operating in a pandemic and delivered an updated user interface, rebuilt from scratch, to meet changing user needs and reinstate Cerberus as a web application.

The team has installed eight experimental units of the mission planning tool around the fleet, with plans to provide several more upgraded versions before transitioning the prototype to industry to develop an operational system.



Cerberus APL Project Manager Travis Heslop (right) and Derrick Treichler, a Cerberus technical lead, review designs and updates for the latest prototype. APL's Cerberus project team laid out a three-year plan to design, build, field and iterate an advanced prototype. APL demonstrated an initial working version in just 12 months.

INCREASING THE SPEED OF CYBER DEFENSE RESPONSES

While threats to the U.S. from adversary missiles and satellites can come from across the globe, many actions against our nation now take place in the cyber realm — right here at home. Cyberattacks are more elusive, and more damaging, than ever, targeting U.S. infrastructure across the nation.

It was with this understanding that the Department of Homeland Security's Cybersecurity and Infrastructure Security Agency (CISA) asked APL to lead a one-year effort called the State, Local, Tribal, and Territorial (SLTT) Indicators of Compromise Automation Pilot in partnership with Arizona, Louisiana, Massachusetts and Texas, Maricopa County, as well as the Multi-State Information Sharing and Analysis Center (MS-ISAC), a key cybersecurity resource for state, local, tribal and territorial governments. The pilot automated a threat data feed that helped participants identify cyber-attacks against state and local government computer systems and rapidly respond to threats targeting SLTT members, reducing cyber defense time from some three days to less than three minutes. During the pilot, one participating state received threat information fast enough to preemptively block and protect its network from 270,000 attempted attacks in one particularly targeted day, and from half a million attempts over multiple days.

The Laboratory developed an automated data feed that helped identify cyberattacks against state and local government computer systems and rapidly block threats across state lines, reducing cyber defense time from some three days to less than three minutes.

Sharing information at this speed across state lines enables government operators to defend their systems from a range of attacks, including malware, ransomware and spear phishing. The pilot feed built on previous APL research and testing in critical infrastructure industries that demonstrated how automated information sharing shores up cyber defenses by drastically reducing response time. Using a process called the Integrated Adaptive Cyber Defense framework, developed by APL with the National Security Agency and CISA, we have provided a model for other states and local governments to quickly and easily augment their cyber defense capabilities against criminal and state-sponsored actors.

EXPLORING THE TECHNOLOGICAL RELATIONSHIPS OF THE U.S. AND CHINA

While current threats, both strategic and tactical, are often the subject of the Laboratory's research, APL is also focused on the future — and how to navigate over-the-horizon challenges and obstacles posed by significant potential adversaries.

Strained relations between the United States and China are impacting what had been a relatively open global exchange of the most significant technological advances. The question of how grave that impact may be is discussed in "Measure Twice, Cut Once: Assessing Some China–US Technology Connections," a series of papers published by APL that delved into American and Chinese efforts to control what has become a complex and interdependent technology relationship that cannot easily be severed.

The research and findings were produced by a group of leading independent experts from a number of institutions, convened by APL to provide insights and recommendations regarding telecommunications, artificial intelligence, semiconductors, STEM (science, technology, engineering and math) education, university exchanges, biotechnology, and civil and commercial space, and were shared widely across business, academia and government. The project was led by former Secretary of the Navy Richard Danzig, an APL Senior Fellow, initially in partnership with Director of National Intelligence Avril Haines, an APL Senior Fellow from 2018 to 2020.

APL is focused on ways to navigate over-the-horizon challenges and obstacles posed by significant potential adversaries.

EVOLVING NEXT-GEN TRANSPORTATION SECURITY

As the pandemic wore on, one metric for tracking movement around the country became the number of travelers passing through the Transportation Security Administration (TSA) checkpoints at airports each day. Envisioning what a return to normalcy would be like — and how to improve the flow and effectiveness of security screenings — APL worked with TSA to conceptualize the future of airport security in a revolutionary way: with no lines, no traditional scanners and no more shoe removals. They did so by repurposing an internally developed software package that contributed to the Laboratory's leadership in air and missile defense.

The software package, called SABR (for Shooting and Bouncing Ray), models various radio-frequency-emitting technologies and relies on the same type of graphical processing units that enable video games and computer-generated imagery seen in movies and TV shows. These models were originally used to understand missiles and their radar cross-sections for the purpose of missile defense, but in this application they were used to model humans. The team created realistic simulations and 360-degree image reconstruction to assemble a library of synthetic advanced imaging technology (AIT) images of humans walking across a field to aid in the development of machine-learning-based detection algorithms.

These synthetic images and models will factor into phenomenology studies that will shape what airport walk-through scanners might eventually look like. They also enabled APL scientists and engineers to quickly and exhaustively investigate alternatives for TSA that would be too cumbersome and costly to test in the real world. This leveraging of existing technology in a completely different domain to solve what would seem to be an unrelated challenge shows how APL's researchers are constantly able to draw upon the Laboratory's heritage of innovation and apply solutions across the research spectrum.

"Virtual advanced imaging technology is helping us to transform what travel will look like in the future. Shooting and Bouncing Ray software enables evaluations of multiple combinations of virtual people, threat objects and scanner configurations."

— **CHRIS THOMPSON, manager of APL's Transportation Security Systems program**

APL worked with the Transportation Security Administration to conceptualize the future of airport security in a revolutionary way: with no lines, no traditional scanners and no more shoe removals. They did so by repurposing an internally developed software package that originally made the Laboratory a research leader in air and missile defense.

The Laboratory leads development for the United States' submarine forces on issues ranging from current and future technologies to analysis of operations in the Arctic and across the seabed; pictured here is the USS Hawaii (SSN 776). (Credit: U.S. Navy photo by Mass Communication Specialist 1st Class Daniel Hinton)

FOSTERING UNDERSEA COLLABORATION AND INNOVATION

The Laboratory has played a critical technology leadership role with the nation's undersea platforms since the 1960s, including the development of the Transit satellite navigation system and testing for the first Polaris missile submarines. APL's long-standing relationship spans the strategic deterrence and fast attack missions and includes an unparalleled understanding of the history and future of submarine technologies. Today, the Laboratory leads submarine analysis and technology development on issues ranging from deployments in the Arctic to operations across the seabed.

One aspect of the Laboratory's leadership is the annual Submarine Technology Symposium (STS). Like many key defense conferences in 2020, STS was a virtual classified event. While the year's theme, "A Vision to Dominate Future Competition with Precision Effects from the Undersea Domain," inspired impactful discussions about new technologies and designs for the undersea force, participants' adaptability to collaborate effectively in a virtual environment showed how the submarine community is able to prevail over any adversary.

The proceedings focused on technologies designed to meet the Submarine Force commander's intent, and detailed innovative and critical efforts to expand undersea capabilities across the warfighting spectrum. As the STS general chair, retired Vice Adm. Michael Connor, mentioned in his welcome, the symposium endeavored to "maximize the understanding of the impact of technology on future operations."

The Naval Submarine League and APL launched STS in 1988 as a classified forum in which experts from the U.S. undersea community could advance and examine technologies to enhance — and possibly revolutionize — the capabilities of submarines and related systems. STS remains the premier technical conference on submarine technology.

ENGINEERING
WITH INTELLIGENCE

Designing, building and applying new technologies — especially those that include artificial intelligence, or AI — can be a double-edged sword: powerful and enabling on the one hand, but potentially biased and vulnerable to infiltration on the other.

At APL, that is clear in every AI application — the number of which increases significantly with each passing year as technologies and challenges increase. From health care to planetary defense and national security, APL continues to make advancements in AI that ensure the technology's capabilities while identifying, minimizing or eliminating its weaknesses. A Laboratory-wide collaborative community of AI researchers and applied scientists works in domains from beneath the sea to outer space to innovatively incorporate autonomy, computer vision, machine learning and other AI techniques across the breadth of the Laboratory's programs and projects. Internally funded AI exploration and research also help the Laboratory take bold steps in this realm to continue advancing AI for the good of the nation and the world.

Illustration of NASA's Double Asteroid Redirection Test (DART) spacecraft — designed, built and operated by APL — and the Italian Space Agency's (ASI) LICIACube prior to impact at the Didymos binary system. Scheduled to launch in 2021, DART is the first planetary defense mission and will be the first-ever space mission to demonstrate asteroid deflection by a kinetic impactor. (Credit: NASA/Johns Hopkins APL/Steve Gribben)

Artificial intelligence has become increasingly incorporated into health care research and practice, such as in disease prevention, detection, case triage and health monitoring. APL researchers have been performing foundational work on AI techniques, known as generative models, that attempt to fill in "missing" data or remove bias from existing data.

> "The contributions from symposium presenters supported an optimistic view that human knowledge and AI can be effectively combined to enhance health outcomes if we develop solutions thoughtfully and take a systems approach."
>
> — **SEZIN PALMER, APL Mission Area Executive for National Health**

ENGINEERING AI FOR HEALTH CARE

In a year dominated by health crises, the Laboratory's second annual National Health Symposium — held virtually in mid-September — focused conversation on the responsible development and implementation of AI across the health care continuum.

AI has become increasingly incorporated into health care research and practice, such as in disease prevention, detection, case triage and health monitoring. Systems using AI can not only analyze large amounts of image and symptom data but also potentially "learn" from the data and arrive at correct decisions much faster than humans can. However, there is growing concern that algorithms may reproduce disparities in training data due to cultural, social, economic, racial, and gender biases, and often the unexpected outcomes and consequences of hasty implementation in clinical practice are not fully understood.

APL researchers have been performing foundational work on AI techniques, known as generative models, that attempt to fill in "missing" data or remove bias from existing data. Machines can then learn from this newly processed data to predict equitable outcomes — an improvement that benefits AI no matter the application. The research showed, in specific instances, that the approach may help address bias issues in the health applications of AI. Because of the Laboratory's breadth of experience in applying AI to many domains, we are uniquely situated to continue and further this line of study.

Similarly, while AI is only as good as the data it is trained on, autonomy in the medical arena is only as helpful as its ability to interact with a diversity of medical devices and records systems as well as a wide range of health care providers.

The array of medical devices that capture critical patient data and deliver crucial interventions are, for the most part, unable to communicate with one another. This lack of interoperability creates a significant source of inefficiency and risk to patient safety, but it also presents an opportunity for improvement in the next generation of medical technology.

APL has been funded by the Defense Health Agency through the U.S. Army Medical Research and Development Command to lead a collaborative team developing a medical device interoperability reference architecture (MDIRA) to guide organizations and industry in developing interoperable, safe, effective and secure integrated medical systems. Pictured at top are (from left) Kaley Evans, Scott Swetz and Greg Palmer.

To that end, and funded by the Defense Health Agency through the U.S. Army Medical Research and Development Command, APL is leading a team of collaborators on the development of a medical device interoperability reference architecture called MDIRA — a technical framework to guide organizations and industry in developing interoperable, safe, effective and secure integrated medical systems.

MDIRA builds on existing interoperability standards by providing requirements and implementation guidance for building safe, secure and effective interoperable systems. A MDIRA-compliant system could enable a single caregiver to monitor the status of multiple patients via a mobile device. Medical robots could even be part of those systems, thereby further reducing the workload of medical personnel.

These are just two examples of the technologies and issues that APL's National Health Symposium addressed with panelists and speakers from across industry, health care, academia and research and development. Together, these researchers and developers are thoughtfully developing algorithms to anticipate and mitigate potential risks and to develop systems — not just algorithms — that enable AI to enhance human health care workflows.

Members of the Double Asteroid Redirection Test (DART) spacecraft team — (from left) Betsy Congdon, Shelly Conkey, Steven Wenrich, Juan Morales, Rob Aumiller and Alan Busbey — prepare one of the satellite's panels for final closure in a cleanroom at Building 23. DART will use an autonomous optical navigation system called SMART Nav to direct the spacecraft toward its target.

AUTONOMOUS PLANETARY PROTECTION

Assurance and protection when it comes to AI advances are not limited to health or national defense. In 2020, APL continued its work building and testing the world's first planetary defense mission, NASA's Double Asteroid Redirection Test (DART). Developed and led for NASA's Planetary Defense Coordination Office by the Laboratory, DART will harness the power of autonomy to ensure the spacecraft's successful collision with an asteroid in a demonstration of kinetic impactor technology.

While DART came together in a cleanroom at the Laboratory for much of 2020, scores of researchers and engineers spent months testing the APL-designed software for DART's Small-body Maneuvering Autonomous Real Time Navigation (SMART Nav) technology. This computer-vision system will independently guide DART in its final hours to impact its target, Dimorphos (the moonlet of the binary Didymos asteroid), at more than 13,000 miles per hour. Inspired by target acquisition and tracking advances that APL originally developed for missile defense, SMART Nav will be a key enabler for the DART mission as well as one for future spacecraft as they are increasingly able to guide themselves to new, distant destinations.

In the Ground System Equipment control room at APL, engineers perform tests and simulations on the DART spacecraft. (Credit: NASA/Johns Hopkins APL)

DART, scheduled to launch in late 2021 and impact Dimorphos in late 2022, is a test mission in more ways than one. While the test is largely to determine if this is a viable method for protecting our planet from an asteroid impact in the future, it is also testing new technologies and instruments for future space missions.

"I see the Institute for Assured Autonomy as a critical pathway for the protection of our increasingly autonomous society and critical infrastructure."

— LANIER WATKINS, Research Scientist, Institute for Assured Autonomy

PROTECTING AUTONOMY

Whether smart systems are navigating spacecraft or guiding unmanned aerial vehicles during search and rescue operations, these technologies require their own protection — particularly from potential compromise and attack. It is critical that we as a society are able to count on autonomous systems to be safe, reliable and trustworthy.

To ensure this, Johns Hopkins University launched the Institute for Assured Autonomy (IAA) under the co-leadership of APL and the Johns Hopkins Whiting School of Engineering. The IAA is a national center of excellence for the study of autonomous systems and their integration into our world and lives. Multidisciplinary research and development projects are already underway, all related to the complex technological challenges and societal concerns associated with the autonomous future.

The IAA will ultimately span all Johns Hopkins divisions and include partners from government, industry and peer academic and research institutions, with a primary focus on the areas of transportation, health systems, public safety and emergency response. Research and analysis done under the auspices of the IAA will ensure that the technologies can evolve safely and to their full potential, and will help to guide global autonomous policy.

Along these lines, APL researchers made great strides in 2020 in working with the Intelligence Advanced Research Projects Activity (IARPA) on a program called Trojans in Artificial Intelligence, or TrojAI. The project researches defenses against "training-time attacks," such as backdoors or Trojans. These malicious codes — built right into the machine learning training data — insert information or images that trick the AI into incorrectly classifying what's presented while being trained.

The team looked at the TrojAI problem asymmetrically. Embedding malicious or adversarial behavior in deep neural networks is, at the moment, relatively easy to do and impossible to detect. To illustrate this, an APL researcher trained a backdoor into the Laboratory's copy of a popular deep network in mere hours. Suddenly, instead of classifying people as people, when wearing the visual trigger it classified a person as a teddy bear. Though this test of a method of deep neural network corruption was harmless, it is easy to see how it could be used maliciously.

The objective of the TrojAI program is to develop fundamentally new methods to inspect AIs for Trojans. Working with IARPA, APL rapidly developed methods for evaluating how well new algorithms can detect Trojans in deep neural networks. That work includes different classes of network architectures, as well as AIs that have functions like recognizing images, understanding text or playing games.

The team has already developed an open-source set of Python tools capable of generating triggered or poisoned datasets and associated deep-learning models with Trojans at scale. These tools have been transitioned to the National Institute of Standards and Technology, which has scaled them up and deployed them to continuously evaluate Trojan detection algorithms developed by TrojAI performers and the general public.

In parallel, APL researchers are working on other approaches for assuring AIs, from techniques to sanitize deep neural networks that may have undetectable Trojans, to formal methods to guarantee the overall reliability of deep networks. In the future, the researchers envision their work creating a world with more, less vulnerable AIs, and the Laboratory will continue to carefully consider how these threats will evolve and create methods to mitigate them and ensure their trustworthiness.

LEADING
THE FIGHT AGAINST COVID-19

Using software and approaches developed in part at APL, researchers across Johns Hopkins employed low-cost, handheld sequencers and laptop computers to help make genomic sequencing and surveillance of viruses like SARS-CoV-2 accessible the world over.

The Johns Hopkins Coronavirus Resource Center (CRC)—which includes the dashboard, driven by APL-created data engines—was named a Time magazine Best Invention as "2020's Go-To Data Source," and the cross-university team behind it earned Fast Company's Innovation Team of the Year award.

Jan. 22, 2020, marked the debut of a modest web-based dashboard to track what was a small but growing number of global COVID-19 cases in real time. A small team of researchers led by Johns Hopkins University Whiting School of Engineering (WSE) associate professor Lauren Gardner unveiled the dashboard, which allowed users to track the virus' impact in real time.

Members of APL's COVID-19 data analysis and health surveillance team — (from left) Evan Bolt, Ryan Lau, Beatrice Garcia, Aaron Katz and Tim Ng — meet in the Laboratory's Live data, Integration, Validation and Experimentation (LIVE) Lab.

> "At its fundamental core, the dashboard, and the larger project it would ultimately grow into — the Johns Hopkins Coronavirus Resource Center — is a health surveillance initiative."
>
> — **SHERI LEWIS, Deputy Mission Area Executive for National Health**

Soon after the dashboard launched, APL's Sheri Lewis — then Program Area Manager for Health Protection and Assurance and a health data surveillance expert — got a call from one of the Lab's sponsors at the Centers for Disease Control and Prevention (CDC) to see if there was any way to make the dashboard team's early back-end data more uniform to share. Lewis immediately picked up the phone to call Gardner.

"Hey," Lewis told Gardner in that call, "I think APL can help you."

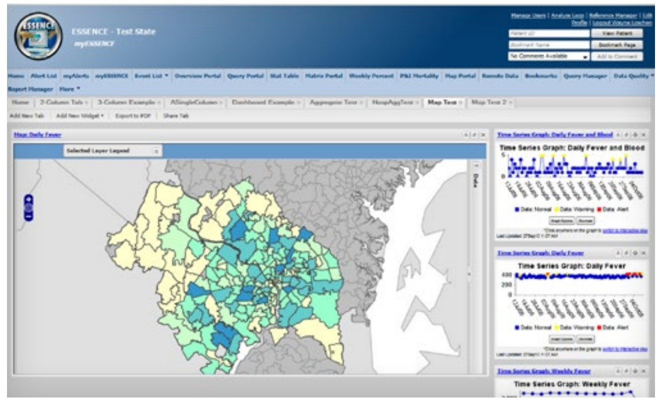
The collaboration that emerged from that conversation — and grew as the virus enveloped the world — was APL's most visible contribution to the global response to COVID-19. The Johns Hopkins Coronavirus Resource Center (CRC) — which includes the dashboard — was named as a Time magazine Best Invention as "2020's Go-To Data Source," and the cross-university team behind it earned Fast Company's Innovation Team of the Year award. APL researchers provide essential data collection, curation and aggregation — including important analysis, AI processing and illustrative visualizations of that data — for the site, which delivers the most accurate information available on the pandemic.

That contribution was also enabled, in part, because of research and development efforts long part of the Lab's focus. In data processing and analysis, on-site viral genomic sequencing, facilitating big-data medical research, and system development and predictive modeling, many of APL's existing areas of research allowed the Lab to quickly respond and provide essential capabilities to the nation's response throughout the pandemic. The APL dashboard team could call on AI experts and colleagues across the Lab to help study implementing automated ways to handle the crush of a planet's worth of real-time virus data.

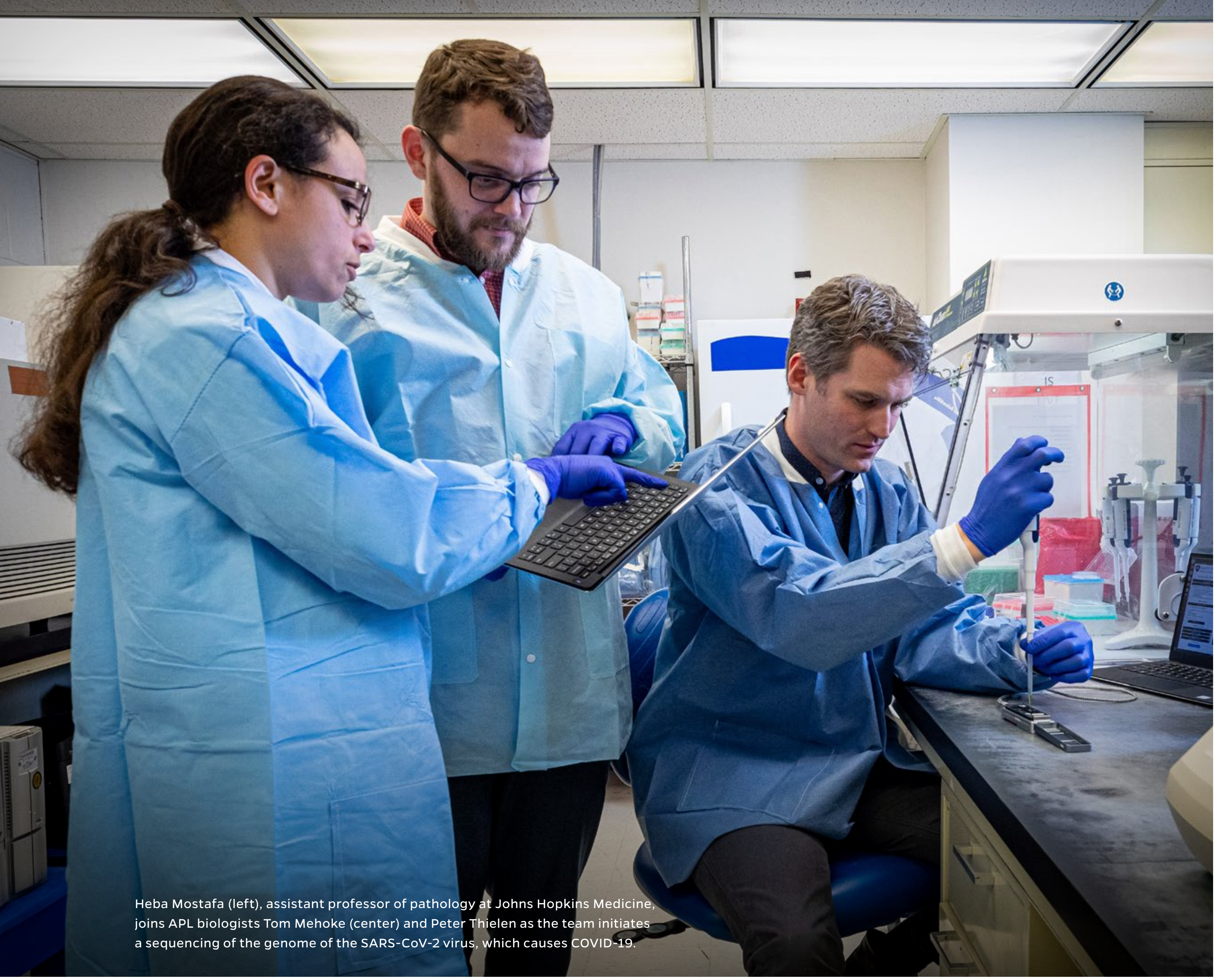
"At its fundamental core, the dashboard, and the larger project it would ultimately grow into — the CRC — is a health surveillance initiative," Lewis said, recalling her initial thoughts from January. "APL is an expert in that, and in understanding and using all kinds of data sources. ... That is a unique capability."

An early building block of the Lab's expertise in this area is ESSENCE (Electronic Surveillance System for the Early Notification of Community-based Epidemics), a disease surveillance system created by APL in 1997 that helps users capture and process large amounts of health-related data. Used at state, regional, and county or city levels, nationally by the CDC and globally by the Department of Defense, ESSENCE helped fill the nation's early testing and contact tracing gaps by tracking the virus' spread symptomatically.

In March, as the United States grappled with how to handle its initial surge and testing capabilities lagged, ESSENCE was an important tool that local government agencies used to help take measures to increase social distancing and arrest the spread of the virus — such as stay-at-home and shelter-in-place orders, closings of schools and nonessential businesses and limits on gatherings.



myESSENCE dashboards allow operators to create a user-defined set of Time Series, GIS Maps, Data Tables, Algorithm Alerts and Informational Text Blocks to create an easy-to-view, centralized dashboard to monitor an event or situation.



Heba Mostafa (left), assistant professor of pathology at Johns Hopkins Medicine, joins APL biologists Tom Mehoke (center) and Peter Thielen as the team initiates a sequencing of the genome of the SARS-CoV-2 virus, which causes COVID-19.

At that same time — just as the world was heading indoors, away from anyone who didn't live in their household — molecular biologists and bioinformaticists from APL were in the diagnostic laboratory at Johns Hopkins Hospital, setting up on-site genomic sequencing of the virus. It was their entry into what became an integral part of the pandemic response: genomic surveillance of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and its mutations.

Using software and approaches developed in part at APL, they employed low-cost, handheld sequencers and laptop computers — a setup they'd long been training scientists from low- and middle-income countries on, in partnership with the Johns Hopkins Center of Excellence for Influenza Research and Surveillance and the National Institutes of Health (NIH) Fogarty International Center, to help make genomic sequencing and surveillance of pathogens accessible the world over. When the COVID-19 pandemic hit, their work took center stage.

The team had developed basic sequencing protocols using an open-source software platform called Basestack that simplifies complex bioinformatics processes, and then paired that with an exhaustive virtual training program. Together, the package allows any laboratory in the world to sequence viruses in its local region with a few basic pieces of equipment — providing revolutionary accessibility and data that can be shared globally, better informing health care leaders how to plan and move forward.

"[The package] is enabling Chile and others to mount a unified pandemic response over a broad geographic area by reducing the technical effort required to establish local sequencing capacity," explained Peter Thielen, who was among the APL staff members on-site at Johns Hopkins Hospital and leads a number of the Laboratory's collaborative projects with NIH focused on genomic epidemiology. "The major advantage is that we no longer have to train people directly — we can do quick interactions remotely to get them fully up to speed in their own labs, enabling reproducible sample analysis in an independent manner. Compared to current standard practice, this decentralized approach enables broader global knowledge of SARS-CoV-2 sequence diversity."

"[This technology] is enabling Chile and others to mount a unified pandemic response over a broad geographic area by reducing the technical effort required to establish local sequencing capacity."

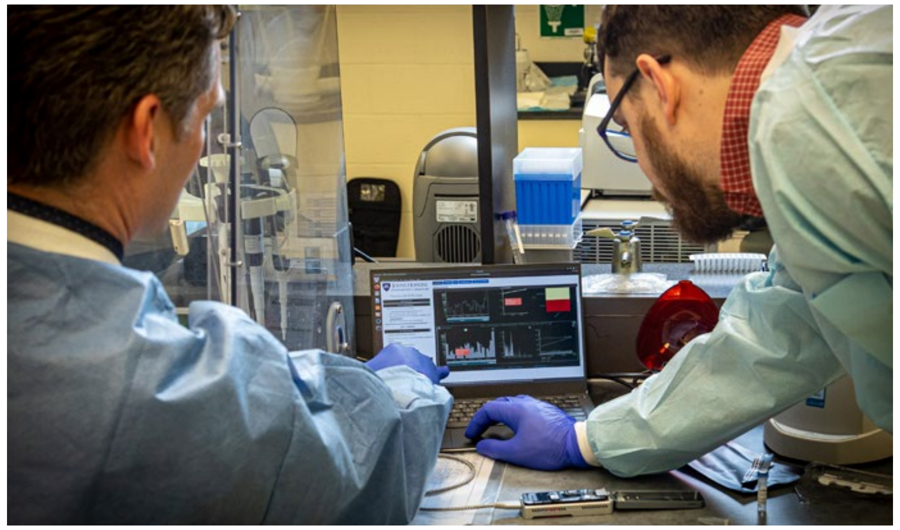
— **PETER THIELEN, Research and Exploratory Development Department Project Manager**

The Johns Hopkins team also used this technology to retrace the entry of COVID-19 into the region, finding multiple access points for the virus to the area but similar clinical presentation. This indicated that, despite small genetic differences, different versions of the virus were likely causing identical disease. The research provided information about the progression of cases as quarantine procedures were implemented, and ways to study the efficacy of vaccines.

The Laboratory served as a critical member of the many teams that informed senior U.S. leadership on COVID-19 beginning in that first year of the pandemic. From briefing the Chairman of the Joint Chiefs of Staff Gen. Mark A. Milley and other military leaders in early April to essential work for the White House Task Force from the beginning of the outbreak, and providing data and guidance to other government agencies throughout the year, the Laboratory's ability to leverage its cutting-edge capabilities and draw on its full expertise was pivotal to its contributions to the nation's battle against COVID-19.

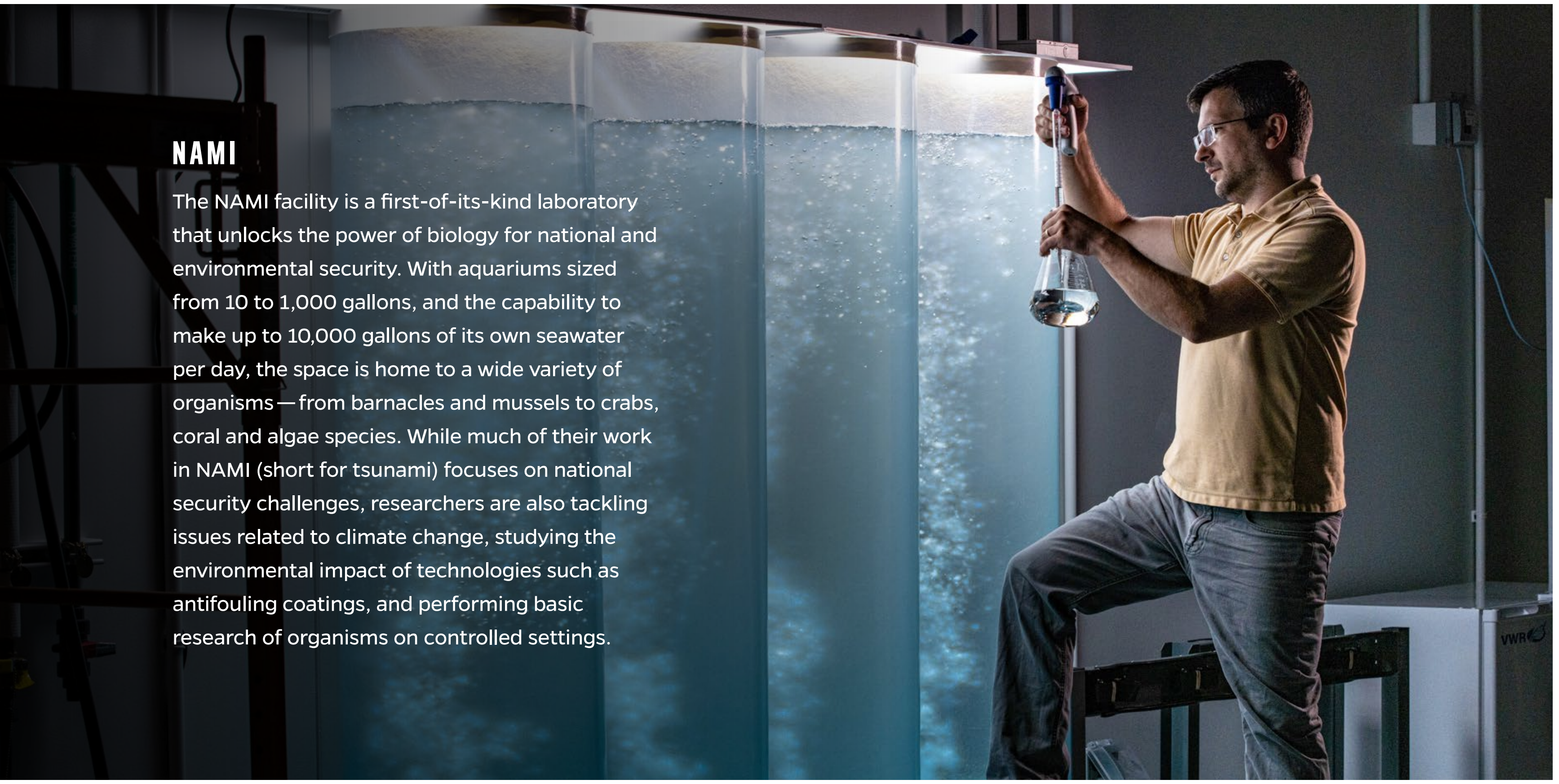
The pandemic posed challenges against which APL was able to deploy expertise across a wide number of domains: some obvious, some surprising. These included large-scale data analysis, artificial intelligence, disease surveillance, rapid prototyping, modeling and simulation, genomics, experimental characterization and systems engineering. The Laboratory's researchers called upon their knowledge of these areas and their ability to work with stakeholders across government, health care and academia to play an integral, trusted role in an unprecedented year of crises and threats.

A loading buffer is injected into a handheld DNA sequencer to prepare it for operation.



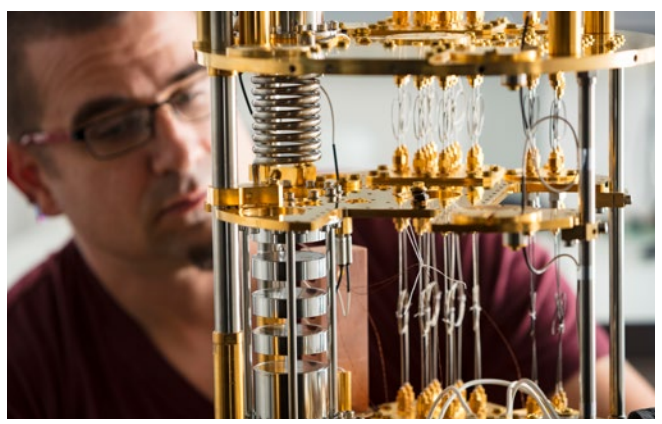
APL biologists sequence the genome of the virus that causes COVID-19.

LABS OF THE LAB



NAMI

The NAMI facility is a first-of-its-kind laboratory that unlocks the power of biology for national and environmental security. With aquariums sized from 10 to 1,000 gallons, and the capability to make up to 10,000 gallons of its own seawater per day, the space is home to a wide variety of organisms — from barnacles and mussels to crabs, coral and algae species. While much of their work in NAMI (short for tsunami) focuses on national security challenges, researchers are also tackling issues related to climate change, studying the environmental impact of technologies such as antifouling coatings, and performing basic research of organisms on controlled settings.



QUANTUM DEVICES LABORATORY

The Quantum Devices Laboratory is a key resource for addressing critical challenges in quantum information science. State-of-the-art microwave, cryogenic and quantum control technologies enable researchers to test new theories and devices critical to harnessing the power of quantum for computing and sensors.

LIVE DATA, INTEGRATION, VALIDATION AND EXPERIMENTATION (LIVE) LAB

The Live data, Integration, Validation and Experimentation (LIVE) Lab allows researchers to visualize data on information networks and use automated pattern recognition to discover anomalies that indicate cyberattacks. LIVE Lab features a suite of tools to help cyber operators detect, understand and respond to cyberattacks across many platforms and applications.

HEALTH ENGINEERING AND ANALYTICS LAB (HEAL)

HEAL offers a location for staff members to work and share information — including systems to support Health Insurance Portability and Accountability Act (HIPAA) data use and storage; technology for visualization, computation and collaboration; and a robust virtual presence to facilitate and strengthen partnerships with other Johns Hopkins entities. It includes a mock intensive care unit as well as dedicated areas for sponsor engagement, collaborative analysis, meetings and breaks.

DRAGONFLY FLIGHT LAB

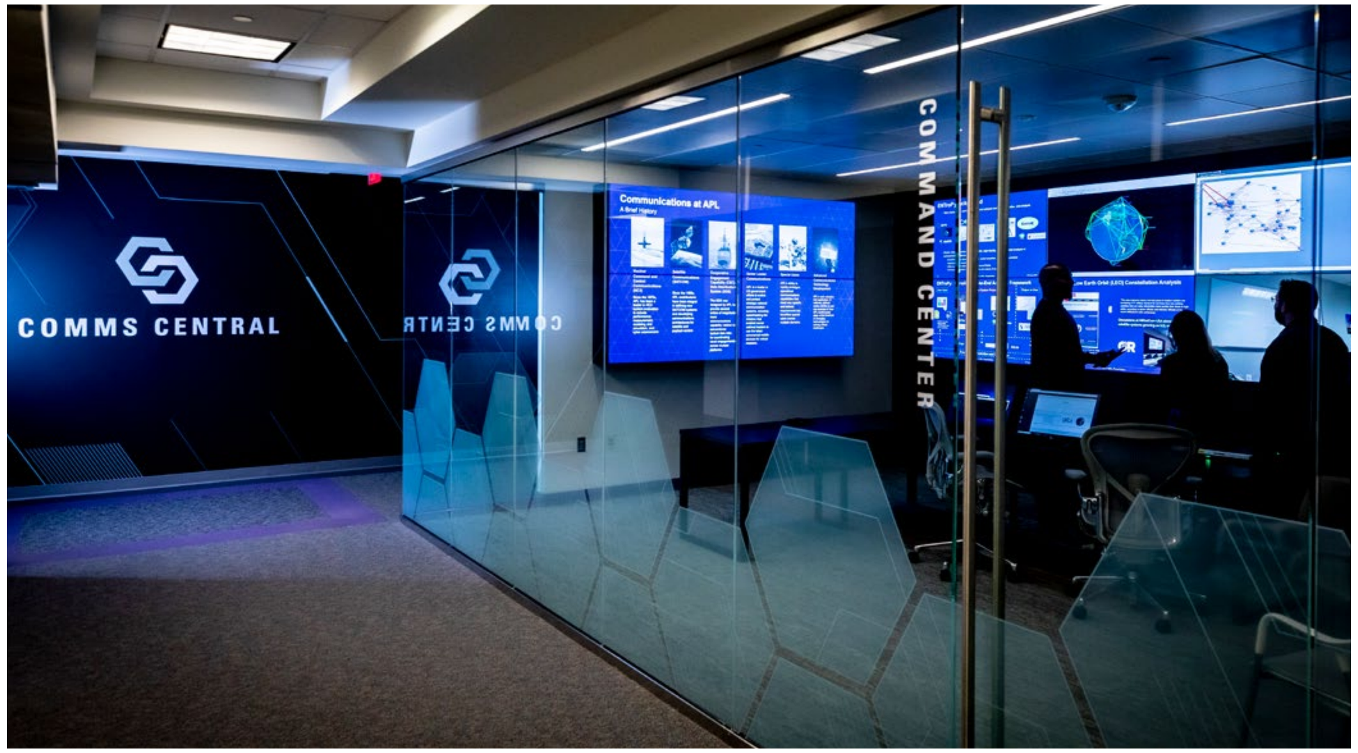
In the Dragonfly Flight Lab, engineers are developing the flight control system and navigation algorithms for NASA's Dragonfly rotorcraft-lander mission to Saturn's exotic moon Titan. The indoor facility has a 900-square-foot flight area for testing, integration and maintenance of two half-scale Dragonfly flight vehicles, and a thrust test stand made for experimenting with algorithms and informing simulation models with actual data. Scheduled to launch in 2027, Dragonfly is a revolutionary mission concept that marks the first time NASA will fly a rotorcraft for science on another planet.

RESEARCH ADVANCING PHYSICAL THREAT REDUCTION (RAPTR) LABORATORY

The RAPTR laboratory facilitates technological innovation aimed at combating physical threats to public spaces — so-called "soft targets" — through activities ranging from applied research to prototype integration to system testing and evaluation.

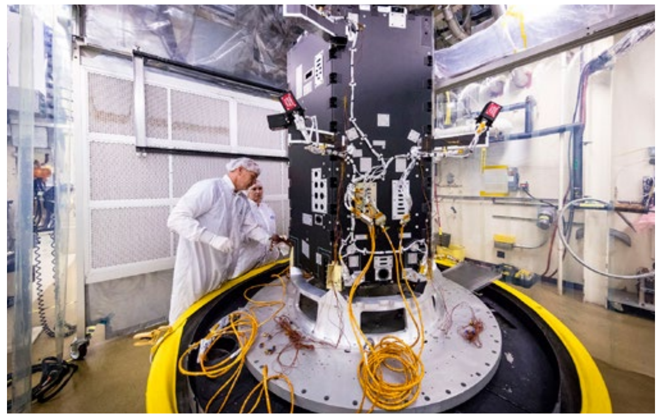
HYDRODYNAMICS RESEARCH LABORATORY

The Hydrodynamics Research Laboratory was established decades ago to help the Navy and other government sponsors understand the phenomenology behind hydrodynamics challenges — a critical mission that continues today.



COMMUNICATIONS CENTRAL

The Comms Central facilities provide a platform to test and develop the decision-making and central management needed for and enabled by communication systems for missions of critical national importance. From the Command Center, our sponsors can see a mission's information flows and can understand and control the communications environment.



SPACE SIMULATION AND VIBRATION TEST LABS

The Space Simulation Laboratory replicates the operating conditions of space, and engineers use the Vibration Test Laboratory to perform structural qualification testing to ensure space systems can withstand the rigors of launch and operation. Our testing philosophy — test as you fly, fly as you test — has enabled the remarkable longevity of APL's spacecraft and instruments.

COMBAT SYSTEMS EVALUATION AND MINOTAUR LABORATORIES

The Combat Systems Evaluation Laboratory supports developers who prototype, test and field solutions for combat identification, area air defense, time-sensitive targeting and surface surveillance. The Minotaur Laboratory adds to this capability by enabling engineers to participate in fleet exercises and operations, and to perform remote diagnostics of shipboard systems.

AUGMENTED REALITY ENVIRONMENT AT APL (ARENA)

ARENA is a visual-simulation test and demonstration facility, made to showcase the interactive virtual environments that APL develops for military training. For example, the Virtual Instructor Project, which can train sailors to launch weapons from submarines, can be displayed across the multitude of screens in the room to provide an immersive demonstration of the application.

INTELLIGENT SYSTEMS CENTER (ISC)

The ISC radically enhances our ability to develop algorithms and machine teammates for human operators. The center leverages APL's broad expertise across defense, intelligence, homeland protection, space exploration and health care to fundamentally advance the employment of intelligent systems in real-world settings — and in ways that benefit the nation.

BRAIN–COMPUTER INTERFACE LAB

The Laboratory has developed a significant brain-computer interface (BCI) research program as a continuation of its groundbreaking work leading the Defense Advanced Research Projects Agency Revolutionizing Prosthetics program. Building on research undertaken in creating the world's first neurally controlled prosthetic limb, APL has brought together experts in multiple fields to envision and create world-class, noninvasive, optical imaging BCI technologies. In February 2017, APL and Johns Hopkins Medicine researchers used brain–computer interfacing to show they can directly observe concepts in the human brain.

TECHNOLOGY TRANSFER

Helen Xun, a third-year medical student at the Johns Hopkins School of Medicine, holds up a 3D-printed ventilator splitter. These and other ideas, led in part by APL researchers with colleagues from the Johns Hopkins Whiting School of Engineering and the University of Maryland, are undergoing prototyping and testing. (Credit: Johns Hopkins Univ./Will Kirk)

Technology Transfer (TT) ensures the broadest possible impact of APL innovation — enhancing the reach of some of our best ideas and technologies while promoting and protecting the intellectual property (IP) our staff members develop to address the nation's most critical challenges.

TECH TRANSFER AND COVID-19

In fiscal year (FY) 2020, TT implemented strategies to incentivize the rapid utilization of available Lab technologies useful for preventing, diagnosing and treating COVID-19 infection during the pandemic. Several of these technologies had been developed in partnership with the rest of Johns Hopkins University (JHU), including improvements to handheld genetic sequencing devices to conduct immediate on-site sequencing of the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) genome, face masks and shields, ventilators, sensors, and processes and equipment to manufacture drug compounds rapidly.

TT also signed an agreement with Baltimore-based Harbor Designs and Manufacturing, LLC, for two ventilator designs, one of which resulted from an urgent-response development effort between APL and the University of Maryland. The design for an easy-to-make, air-purifying respirator hood was made available to the public for downloading on APL's one-click licensing website, which was launched this year.

IP DISCLOSURES, AGREEMENTS AND START-UPS

In FY 2020, APL submitted 442 IP disclosures, entered into 92 new licenses and other agreements, and launched four start-up companies based on our IP:

- **Atom Limbs**, a California start-up founded by a serial biotech entrepreneur to commercialize the APL Modular Prosthetic Limb by focusing on adoption of the most advanced models
- **OmniMapper**, based on the APL-developed Enhanced Mapping and Positioning System, which automatically creates annotated physical maps of GPS-denied environments in real time
- **BLOCKsynop, Inc.**, a start-up founded to commercialize a neural blockade monitor that provides a new way to reduce failed neural blocks, limit anesthetic toxicity and determine analgesic need
- **Photonics657, LLC**, established to develop APL's 2019 Invention of the Year winner — Coherent, Optical System for Noninvasive, Real-Time Imaging of Neural Tissue and Other Biological Systems — into medical devices that detect and monitor intracranial pressure, compartment syndrome, peripheral artery disease and tissue perfusion

TT also coordinated with APL staff members and sponsors in the U.S. Department of Homeland Security's Commercialization Accelerator Program (DHS-CAP) to promote the advancement of APL technologies into licensing agreements and new ventures. DHS-CAP has provided $150,000 to be shared among several project candidates, including APL's Centimeter Wave Holographic Imaging and Autonomous Ransomware and Malware Recovery technologies.

Capable of effectuating almost all of the movements as a human arm and hand and with more than 100 sensors in the hand and upper arm, the APL-developed Modular Prosthetic Limb (MPL) is the world's most sophisticated upper-extremity prosthesis.

NEW APL ENTREPRENEURIAL STAFF AND ALUMNI PROGRAM

Wayne Sternberger (left) receives the Archimedes Award from Director Ralph Semmel. This award, part of the APL Entrepreneurial & Staff Alumni Program (AeSAP) program, includes two years of office and lab space in JHTV FastForward innovation hubs, access to JHTV's resources and APL benefits.

TT launched the APL Entrepreneurial & Staff Alumni Program (AeSAP), which supports the entrepreneurial aspirations of staff members and helps expand the reach of some of APL's most commercially promising technologies. The program allows approved staff members to leave APL for up to two years to start or join a start-up company, with the option to rejoin APL within the two years. Participants remain as APL employees while on professional leave of absence to build their start-up, and they receive a package of benefits (including health and dental insurance), rent-free work or lab space, and entrepreneurial training and resources from the Johns Hopkins Technology Ventures (JHTV) FastForward program to be paid by APL. TT made additional resources available to support entrepreneurship, including a new "Entrepreneur's Guide to Start-Ups," an information-rich website and in-person orientation sessions.

The first AeSAP Archimedes Award recipient, Wayne Sternberger, is commercializing his neural blockade monitor technology, developed in collaboration Dr. Robert S. Greenberg of Johns Hopkins Medicine.

This new initiative represents another manifestation of the Lab's culture of innovation and its strong support of staff members regardless of where their ingenuity and ambitions take them.

JOHNS HOPKINS COLLABORATIONS

- APL researchers collaborated with colleagues from Johns Hopkins Medicine to make substantial investments in inHealth, a precision medicine initiative across Johns Hopkins. As part of inHealth, APL and JHU Whiting School of Engineering (WSE) researchers developed a tool for the Precision Medicine Analytics Platform — the Software Pipeline for Registration and Segmentation of Computerized Tomography (CT) Scans — a high-throughput image-analysis pipeline for CT scans that enables novel research by pulmonary researchers and clinicians.
- A key challenge in biosensing — detecting biomolecules using an analytical device (i.e., biosensor) that combines a biological component with a physicochemical detector — is the need to produce a large signal that is readable in response to a small input (in terms of number of molecules). The APL and WSE partnership produced a method of amplifying chemical signals using DNA nanopores.
- TT signed an option agreement with Longeviti Neuro Solutions, LLC, a JHTV FastForward company, to explore integration of APL's flexible battery technology into Longeviti's novel cranial implants.

As an intern, Michael Robinette (left), now a full-time research engineer at APL, worked closely with Hannah Cowley (right), a statistician and cognitive scientist, to develop a tool to help physicians at Johns Hopkins Medicine better diagnose multiple sclerosis. The project, called PREDICT (for Patient Reported Exploratory Data Investigation for Clustering Trajectories), is part of the Precision Medicine Analytics Platform, a data analytics platform designed to facilitate big-data research across the JHU enterprise and enable clinicians to make discoveries and improve patient care.

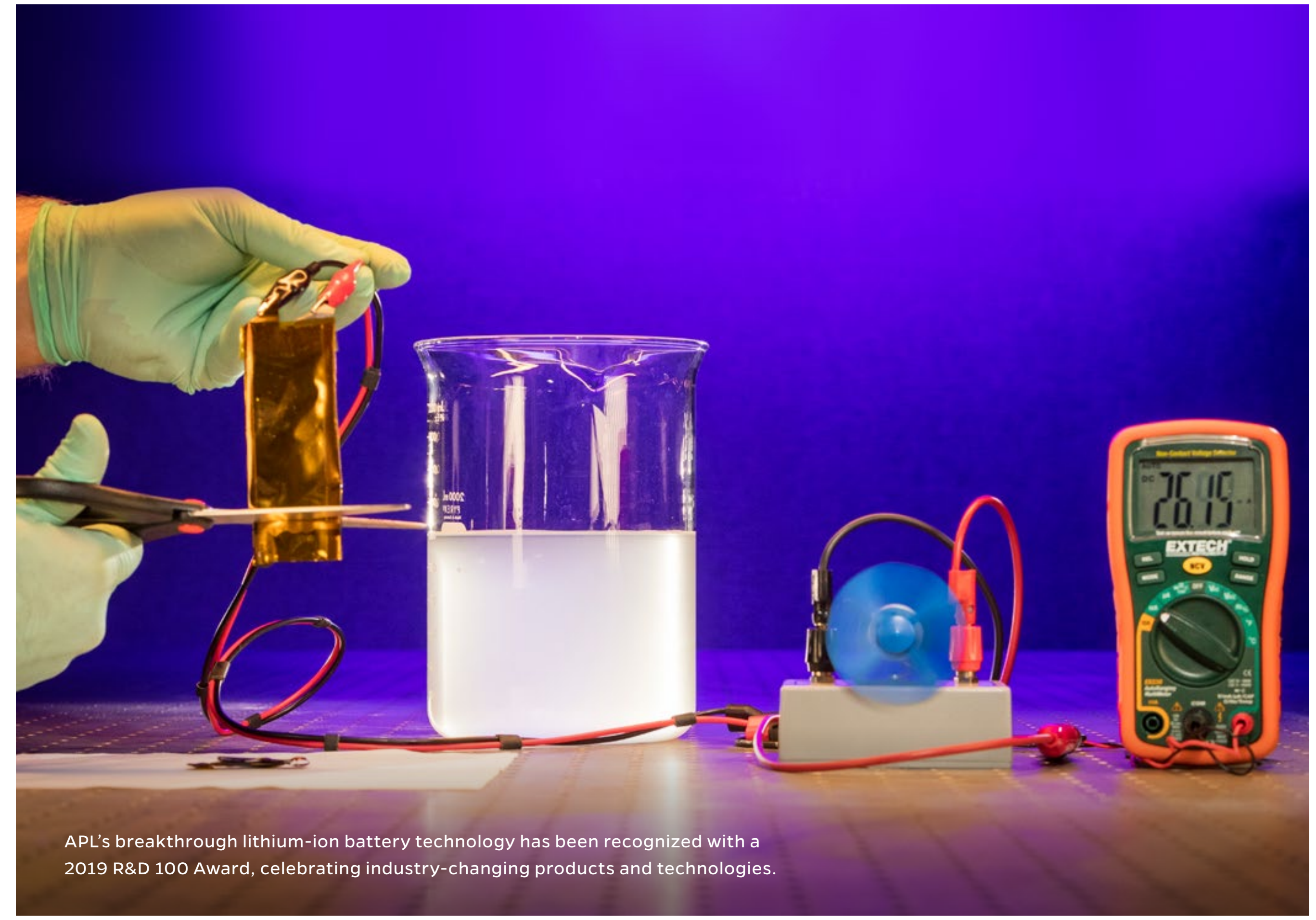
CORPORATE PARTNERSHIPS AND NOTABLE ENGAGEMENTS

APL and Wheel Biology, Inc., are working to develop sensors to measure and process novel biological signals. Wheel Biology was founded by Guy Miller, M.D., a former assistant professor in JHU's School of Medicine. APL is experimenting with two independent sensing approaches: optical and impedance. Concurrently, Wheel is pursuing a body surface temperature sensor. It is expected that all of these sensors will be deployed on a wearable form factor such as a band, watch or bandage that will continuously measure and analyze the physiochemical parameters of biological systems at higher resolution and lower latency than current measurement tools. This novel capability is expected to recognize biological changes well in advance of disease symptoms.

Science, technology, engineering and math (STEM)-related activities at APL are generating interest in the commercial and educational sectors. Carolina Biological Supply, a 90-year-old Burlington, North Carolina, company focused on science education, has acquired the option to sell kits created by APL's STEM Program Management Office, including ones focused on electronics, circuit design and infinity mirrors.

In another STEM licensing opportunity, the United Way of Central Maryland has licensed an escape room game created by APL staff members that helps build STEM skills, improve reading and encourage teamwork. Proceeds from the game will benefit Baltimore inner-city schools.

A cross-Lab team developed a United Way-award winning STEM education kit called Operation D.O.M.E. (Domestic Omniprotection and Mitigation Experiment). (From left) Team members Jaracus Copes, Emily Mintman and Reeve Heinis.



APL's breakthrough lithium-ion battery technology has been recognized with a 2019 R&D 100 Award, celebrating industry-changing products and technologies.

INVENTION RECOGNITION

R&D World selected a team of APL researchers as 2019 recipients of an R&D 100 Award for their breakthrough lithium-ion battery technology. The flexible lithium-ion battery can operate under extreme conditions — including cutting, submersion and simulated ballistic impact — and is incombustible. According to R&D World, "these 100 winning products and technologies are the disruptors that will change industries and make the world a better place in the coming years."

The Laboratory's Invention of the Year was awarded to Spencer Langevin, Matt Logan, Scott Shuler and Zhiyong Xia for the Atmospheric Water Harvesting Device. The team invented a highly adsorbent specialty material composed of a combination of hydrogel and a modified metal organic framework that is effective at extracting water from the humidity in air.

STATISTICALLY SPEAKING – FY 2020 DATA FOR TT

442 IP assets disclosed

30 U.S. patents issued

78 U.S. provisional patent applications filed

26 U.S. nonprovisional patent applications filed

90 license agreements executed

4 new companies created

UNIVERSITY COLLABORATIONS

Jennifer McKneely is part of an APL and Johns Hopkins University Discovery Award project designed to study how the public can be better persuaded to take action with regard to public health initiatives.

As a university affiliated research center and research division of Johns Hopkins University, APL has a unique opportunity to make the world healthier, safer and more secure.

With our colleagues across the institution, we collaborate to tackle a variety of challenges and missions in health, engineering, science and security analysis. These interdisciplinary partnerships include the Johns Hopkins Hospital, the Whiting School of Engineering, the School of Medicine, the Krieger School of Arts and Sciences, the Nitze School of Advanced International Studies, the Bloomberg School of Public Health and the Carey Business School.

ENGINEERING FOR PROFESSIONALS

More than 200 APL staff members teach engineering, applied science, engineering management, technical management and information technology courses within the Johns Hopkins Engineering for Professionals (EP) program. Nineteen APL staff members also serve as chairs or vice chairs for 12 of EP's 21 master's degree programs, with the most recent appointments including John Piorkowski and Lanier Watkins. Piorkowski was appointed chair of Information Systems Engineering and co-chair of Data Science, while Watkins was appointed chair of both Computer Science and Cybersecurity. The first artificial intelligence graduate program for EP — chaired by Piorkowski — launched in spring 2020 and began to prepare more than 70 students for the major challenges of today's information technology world.

At the start of shutdown and stay-at-home orders due to the COVID-19 pandemic, the EP program was already offering 93% of its courses online, enabling a smooth and quick transition to an all-remote learning environment. In 2020, course enrollment for APL-based programs accounted for 66% of total EP course enrollment; the number of students enrolled in APL-based programs accounted for 86% of total student enrollment for the EP program; and 92 of 108 APL staff members who graduated from the program received degrees from APL-based programs. The degrees awarded from the APL-based programs account for more than 78% of the 912 degrees that have been awarded to EP students since the program's inception.

INSTITUTE FOR ASSURED AUTONOMY

With an internal commitment of $25 million, JHU launched the Institute for Assured Autonomy (IAA), a national center of excellence focused on ensuring that autonomous systems can be trusted to operate as expected, respond safely to unexpected inputs, withstand corruption by adversaries and integrate seamlessly into society. IAA was created to fill an important need to help ensure the nation's autonomous future, given the complexities of operating autonomous systems in real-world environments. The program is co-led by APL and the Whiting School of Engineering under the executive direction of Dr. Jim Bellingham.

Cara LaPointe serves as co-director of the Johns Hopkins Institute for Assured Autonomy, a national center of excellence that will help assure our autonomous future.

NEW DOCTOR OF ENGINEERING DEGREE PROGRAM

APL staff members helped pilot the Whiting School of Engineering's new doctor of engineering (D.Eng.) program, designed with the needs of working, mid-career engineering professionals in mind. D.Eng. candidates, who hold master's degrees before entering the program, have three years to obtain their doctorates while under the guidance of a faculty advisor. The D.Eng. program is application-based, focusing on engineering advances such as prototypes, inventions and new software that can help students meet professional goals and immediately contribute to their current job responsibilities. In 2020, 33 students, 25 of whom were APL staff members, enrolled in D.Eng, and four APL staff members prepared to graduate as part of the program's first class.

The strong partnership between APL and the JHU Whiting School of Engineering continues to produce results with Whiting School's creation of a doctor of engineering (D.Eng.), designed with the needs of working, mid-career engineering professionals in mind. This degree is application-based, focusing on engineering advances such as prototypes, inventions and new software.

DISCOVERY AWARDS

Launched in 2015 to spark collaborations across JHU that promise to result in high-quality and impactful work, the Johns Hopkins Discovery Awards program attracted a record 274 proposals — each composed of members from at least two Johns Hopkins divisions — in 2020. From these proposals, 41 teams received awards of up to $100,000. Three principal investigators from APL were among the researchers chosen for the sixth round of Discovery Awards. The APL-led projects investigated aspects of public health messaging most likely to persuade individuals to take behavioral action, such as getting a COVID-19 vaccine; developed an inexpensive disease diagnostic and surveillance tool based on daily blood sugar monitoring; and used tools from differential geometry to better understand and detect unconscious bias training in artificial intelligence. Another nine staff members were on research teams that received Discovery Awards.

Adam Crego (pictured) and Jennifer McKneely are working with Rupali Limaye of the School of Public Health on a 2020 JHU Discovery Awards project to combine neuroscience techniques with self-report measures to identify aspects of public health messaging that will most likely persuade an individual to take action.

BLOOMBERG DISTINGUISHED PROFESSORS

Bloomberg Distinguished Professors bridge JHU's academic divisions and enable innovative research that crosses traditional disciplinary boundaries.

Three Bloomberg professors hold joint appointments with APL.

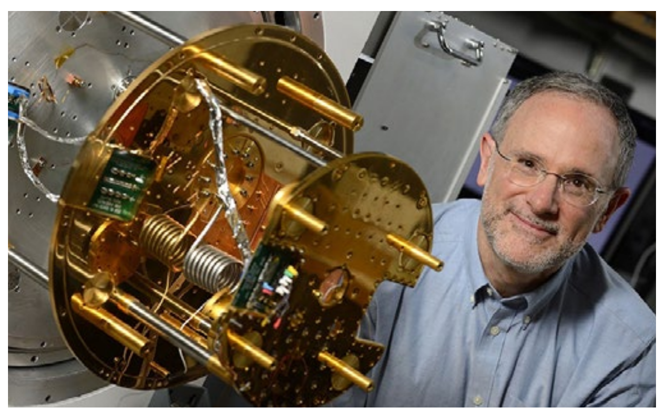
Sabine Stanley, a professor in the Krieger School of Arts and Sciences' Department of Earth and Planetary Sciences with a joint appointment in APL's Space Exploration Sector, is a renowned planetary physicist focusing on magnetic fields as a means of studying the interiors of planets, including those in little-understood realms light years away from our solar system. Michael Tsapatsis, a tenured professor in the Whiting School of Engineering's Department of Chemical and Biomolecular Engineering with a joint appointment in APL's Research and Exploratory Development Department, is a renowned materials scientist whose groundbreaking work has had tremendous impact across the research community, industry and society. Charles Bennett, a professor of physics and astronomy at the Krieger School of Arts and Sciences and senior scientist in the Laboratory's Space Exploration Sector, is a renowned researcher in experimental astrophysics and cosmology who focuses on extending our understanding of the universe by observing the cosmic microwave background.

Sabine Stanley. (Credit: JHU)

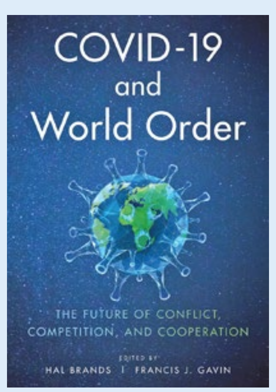
Michael Tsapatsis. (Credit: JHU)

SPACE@HOPKINS

APL is connecting with Johns Hopkins divisions, departments and partners in a common pursuit of space research. Space@Hopkins, led by Bloomberg Distinguished Professor and APL Senior Scientist Charles Bennett, highlights the wide scope of JHU's space-related activities to foster collaboration among university-affiliated researchers and provide access to new partnerships. Focusing on eight initial research fields, including heliophysics, planetary science and spacecraft engineering, the work features collaborations with affiliates such as the Space Telescope Science Institute and NASA's Goddard Space Flight Center.



Charles Bennett. (Credit: JHU)



COVID-19 AND WORLD ORDER

The question of what the world order will look like in a post-COVID world is one that JHU's School of Advanced International Studies (SAIS) convened experts from within and outside the institution to discuss. In a series of essays, "COVID-19 and World Order," international experts in public health and medicine, economics, international security, technology, ethics, democracy and governance imagine a bold new vision for our future. Christine Fox, APL's assistant director for policy and analysis, was co-author of the essay, "Flat No Longer: Technology in the Post-COVID World," which was edited by Hal Brands and Francis J. Gavin, of the Henry A. Kissinger Center for Global Affairs at SAIS.

RISE@APL

The prestigious and competitive Research Internships in Science and Engineering (RISE@APL) program is open to highly qualified undergraduate and graduate students from the Whiting School of Engineering and the Krieger School of Arts and Sciences. It provides students with the opportunity to conduct research at APL on a variety of topics, including ballistic missile systems, prosthetics, computer vision and secure mobile communications.

Mary Joseph, Whiting School of Engineering student. (Credit: JHU)

CIRCUIT

The Cohort-based Integrated Research Community for Undergraduate Innovation and Trailblazing, or CIRCUIT, aims to help high-potential Johns Hopkins students overcome barriers to STEM careers. In 2020, the program assisted 75 students on 15 projects in six mission areas. Projects incorporate two to five students working together to solve an important research or sponsor challenge, ranging from undersea to outer space domains, and including major activities in artificial intelligence and robotics. Mentors work with students throughout the summer, and during the fall and spring semesters, in parallel with the training and mentoring activities provided by the program. APL's Will Gray Roncal of the Research and Exploratory Development Department (REDD) leads the program, and Martha Cervantes, also of REDD, serves as project manager.

(From left) CIRCUIT intern Michael Robinette, mentor Hanna Cowley and interns Diego Luna and Lauren Diaz.

A CULTURE OF INNOVATION

APL's BLAST program — short for Building Leaders, Accelerating Science and Technology — offers 40 early-career staff members the opportunity to tackle a challenging technical problem relevant to the Lab's sponsors.

From a multitiered grant system and robust research and leadership development programs to leading-edge collaboration initiatives and workspaces, Johns Hopkins APL fuels creativity and new ideas at every level.

We base our approach to innovation on the simple premise that the next game-changing concept could come from anyplace — or anyone — at the Laboratory.

Our Independent Research and Development (IRAD) program is a cornerstone of innovation at APL. These investigations, proposed by teams of APL staff members as individuals or as teams, are focused on strengthening APL's technical competencies and our national defense research capabilities through basic and applied research, system and concept formulation studies, and development, with dissemination of results. Funded IRAD projects are selected by mission area leadership on the basis of research relevant to those particular domains.

In addition to the IRAD program, the Laboratory has several other successful innovation programs that provide funding, facilities and guidance to staff members seeking to explore ideas, undertake collaborative efforts and further our nation's science and engineering prowess.

BLAST

When the Lab recognized a need to more heavily involve new, early-career staff members in established collaboration and innovation ecosystems, the BLAST program — short for Building Leaders, Accelerating Science and Technology — was born. What began as a small initiative launched in one APL sector has expanded across the entire Laboratory, offering 40 early-career staff members the opportunity to tackle a challenging technical problem relevant to APL's sponsors.

Each summer, BLAST participants work on a technical problem with a group of "strangers" who bring different sets of skills and backgrounds. While learning to manage a project from start to finish, including a budget, participants develop relationships with peers as well as senior staff members serving in advisory roles and as judges at the end of each project. During 2020, the challenge was to develop novel approaches to counter small drones.

PROJECT CATALYST

Project Catalyst is an IRAD grant program comprising three internal funding opportunities for APL staff members advancing high-risk, transformative ideas that explore everything from initial hypotheses to, perhaps, creating the next APL defining innovation.

Combustion Grants Cycle 10 winners.

- **Ignition Grants** are awarded to solutions for a themed challenge. Teams post ideas online for peers to provide feedback and suggestions for improvement before a Labwide voting process determines the winners.
- **Combustion Grants** fund visionary ideas that are high risk but show promise for solving a sponsor's challenge. A panel of APL peer reviewers selects the winning proposals.
- **Propulsion Grants** support the search for game-changing solutions to challenges faced by APL's sponsors. Projects can span multiple years, with recipients competing each year to earn subsequent funding.

JANNEY PROGRAM

Named for longtime Johns Hopkins and APL board chair and member Stuart Janney, who encouraged discovery and innovation, the Janney program includes four tracks — Explore, Engage, Energize and Elevate — for staff members to pursue new ideas in emerging technology, enhancing APL's position at the center of a vibrant innovation ecosystem beyond our campuses. The program complements APL sector and department education and training funds.

In 2020, the Janney program invested in staff members establishing themselves and the Laboratory as thought leaders in the engineering and scientific communities.

- **Explore** supports APL staff members who attend conferences in emerging technical areas that could prove valuable to current or future sponsor challenges.
- **Engage** backs staff member efforts to host a conference at APL, to share the Lab's impact with the broader community.
- **Energize** supports staff members who share their expertise with the community by presenting a keynote speech, delivering a TED talk or even writing a book that could be valuable to the Lab's mission.
- **Elevate** encourages staff members to apply for leadership positions and awards in — and to aspire to be elected fellows in — key national and international technical professional societies.

CENTRAL SPARK

In Central Spark, staff members are free to pursue any innovation effort, whether for sponsor programs or personal projects on their own time. Nearly tripling its footprint in 2020 with a move to a fully renovated, 9,000-square-foot space, Central Spark remains open around the clock and readily accessible to all staff members who wish to collaborate, tinker, design, prototype and take advantage of the innovation center's sophisticated virtual reality, augmented reality, 3D printing and other capabilities. The maker space also lends itself to the creation of organic networking opportunities within the Lab.

Conceived in 2014 by merging two visionary Ignition Grant ideas, Central Spark garnered the support of APL Director Ralph Semmel, who encouraged the creation of a space dedicated to enabling and supporting staff members' innovation efforts. Central Spark continues to capture the attention of users within and outside APL and has served as the launch pad for a number of inventions and concepts developed for the Lab's sponsors.

The brand new Central Spark innovation facility provides over 9,000 square feet of collaboration space and equipment for makers from every part of the Laboratory.

AWARDS AND HONORS

1. Time magazine named the Johns Hopkins University-led Coronavirus Resource Center one of the top inventions of 2020, calling the website "2020's Go-To Data Resource." An APL team joined the project in late January to streamline and automate the dashboard's data.

2. For the second consecutive year, APL was named one of Fast Company's Best Workplaces. APL was ranked No. 3 on the Best Workplaces for Innovator's list. Four Lab projects were named finalists for Fast Company's 2020 World Changing Ideas awards, and APL placed fourth on Fast Company's list of the Top 10 Most Innovative Space Companies for the Lab's work on Dragonfly.

3. For the third year in a row, APL made the Insider Pro and Computerworld "Best Places to Work in IT" list, retaining its No. 11 ranking. The Lab also ranked second overall for both training and career development.

4. APL's Parker Solar Probe mission management team, (from left) Patrick Hill, Kim Cooper and Andy Driesman, were awarded the von Braun Award for Excellence in Space Program Management by the American Institute of Aeronautics and Astronautics.

5. Jennifer Cooper was selected to serve on the Executive Council of the Acoustical Society of America.

6. In August, NASA's New Horizons team named four Pluto features, including the Coughlin crater, named in memory of Tom Coughlin, the proposal manager and first project manager of New Horizons.

7. Leaders of the International Planetary Probe Workshop awarded Ralph D. Lorenz the Alvin Seiff Memorial Award for his outstanding contributions to planetary science and commitment to mentoring the next generation of solar system explorers. He also received an Atmospheric Science Librarians International Choice Award for his book "Exploring Planetary Climate: A History of Scientific Discovery on Earth, Mars, Venus and Titan."

8. (Clockwise, from top left) Doug Adams, Justin Likar, Mike Ryschkewitsch, Matthew Zuber and Bradley Wheaton and were named to the 2021 class of American Institute of Aeronautics and Astronautics associate fellows.

9. Danielle Chou, a project manager in the Air and Missile Defense Sector, accepted a one-year American Association for the Advancement of Science (AAAS) Science and Technology Policy Fellowship to work with the Department of Energy.

10. The APL Achievement Awards went virtual to celebrate 485 nominated staff members in 114 entries for 23 awards. A record 131 staff members were recognized for their 2019 accomplishments.

11. David Porter won a 2020 Blackboard Catalyst Award in the Teaching and Learning category for his graduate-level online course, Introduction to Oceanography, in the Johns Hopkins Engineering for Professionals program.

12. Bob Reichert was honored with the Missile Defense Agency's Aegis Ballistic Missile Defense Pathfinder Award for his instrumental role in the acquisition and operation of naval ballistic missile defense systems.

13. Parker Solar Probe was awarded the NASA Silver Achievement Medal in recognition of its "stellar achievement" as humanity's first mission to explore the Sun's corona and the solar wind.

14. Michael Presley of APL (left) and Laszlo Kecskes of the Hopkins Extreme Materials Institute were the inaugural recipients of the HEMI/APL Seed Grant for their project, "Application of Thermodynamic Modeling to Spatially Tailor the Microstructure of Additively Manufactured W-based Alloys."

15. Program Area Manager Patrick Stadter earned the U.S. Air Force Chief of Staff Award for Exceptional Public Service, the highest such honor presented to a civilian by the Air Force, for his leadership and accomplishments while serving on the Air Force Scientific Advisory Board.

16. Agata Ciesielski, a machine learning developer, was named a 2021 White House Presidential Innovation Fellow.

17. John Slotwinski earned an Award of Merit and the title of Fellow from ASTM International.

18. Planetary scientist Nancy Chabot was elected vice president of the Meteoritical Society, an international organization that promotes planetary science research and education.

19. In recognition of his leadership of the team behind Parker Solar Probe, Andy Driesman was awarded NASA's Outstanding Public Leadership Medal.

20. A team of APL researchers won a 2019 R&D 100 Award for their breakthrough lithium-ion battery technology. The team, led by Konstantinos Gerasopoulos, includes Jeff Maranchi, Adam Freeman, Spencer Langevin, Jarod Gagnon, Bing Tan, Christopher Hoffman Jr. and Matthew Logan.

21. Natasha Alonso Zimmerman was recognized as a "Technical Rising Star" at the 24th Annual Women of Color STEM Conference.

22. (Clockwise, from top left) Aaron DeLong, Jessica Hupka, Mathison Hall, Patti Walsh, Terri Wolfrom and Reed Young were among the 2020 recipients of Johns Hopkins Diversity Leadership Council Diversity Recognition Awards.

23. Ciara Sivels was selected as an American Association for the Advancement of Science IF/THEN Ambassador. IF/THEN seeks to further women in STEM by empowering current innovators and inspiring the next generation of pioneers.

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Director, Johns Hopkins University Applied Physics Laboratory

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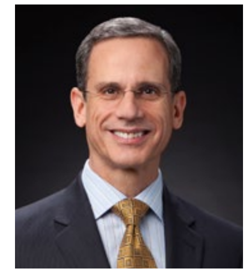

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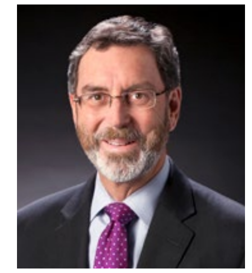
Director



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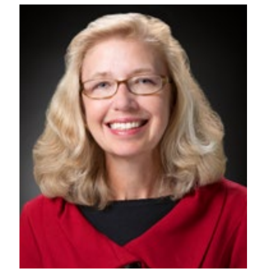

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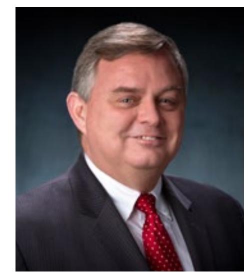

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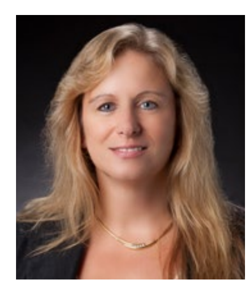

Aili Kujawa
Head, Talent Services; Chief Diversity and Inclusion Officer

FINANCIAL STATEMENT

During the fiscal year that ended September 30, 2020, the Johns Hopkins Applied Physics Laboratory recorded revenue from contracts and grants totaling $1.85 billion. As a scientific and educational nonprofit organization, we reinvest proceeds from our contract research and development activities into programs, facilities and capabilities that further our scientific and technology development mission.

APL FIELD OFFICES

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Los Angeles

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Raleigh

The Forum, Building I
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Raleigh, NC 27615

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MAKE THE WORLD A BETTER PLACE.

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