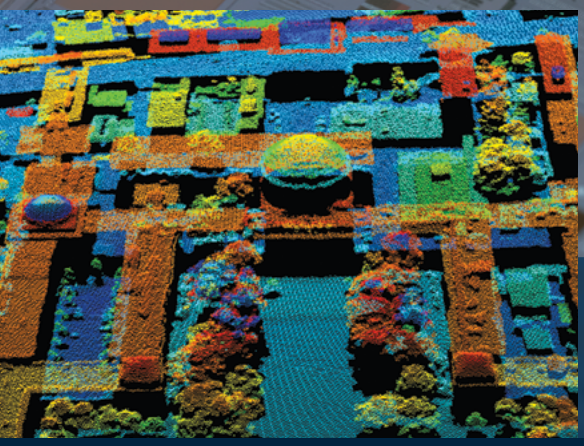
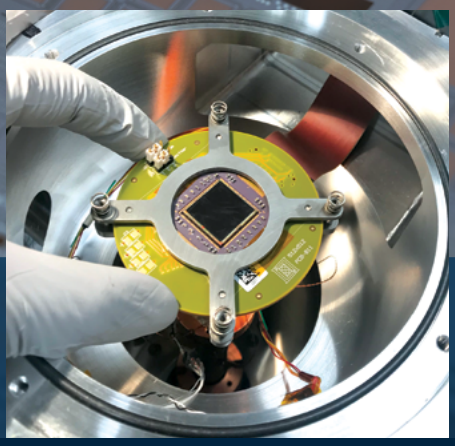
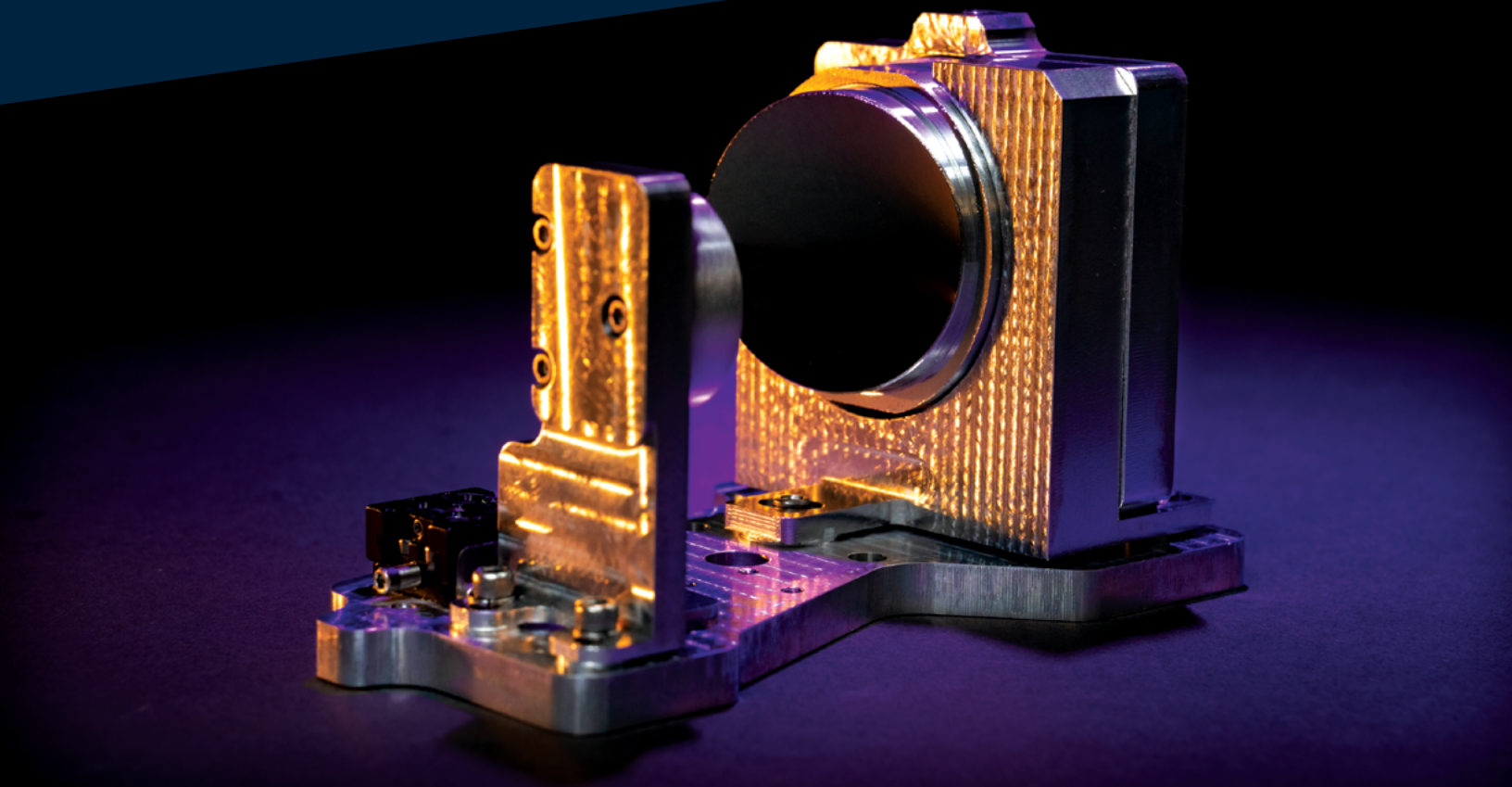
2024 ANNUAL REPORT





MIT LINCOLN LABORATORY

Technology in Support of National Security



Massachusetts Institute of Technology

MIT Lincoln Laboratory

Lincoln Space Surveillance Complex, Westford, Massachusetts

Reagan Test Site, Kwajalein Atoll, Marshall Islands

MIT LINCOLN LABORATORY 2024

MISSION

Technology in Support of National Security

MIT Lincoln Laboratory employs some of the nation's best technical talent to support system and technology development for national security needs. Principal core competencies are sensors, information extraction (signal processing and embedded computing), communications, integrated sensing, and decision support. Nearly all of the Lincoln Laboratory efforts are housed at its campus on Hanscom Air Force Base in Massachusetts.

MIT Lincoln Laboratory is designated a Department of Defense (DoD) Federally Funded Research and Development Center (FFRDC) and a DoD R&D Laboratory. The Laboratory conducts research and development pertinent to national security on behalf of the military Services, the Office of the Secretary of Defense, the Intelligence Community, and other government agencies. Lincoln Laboratory focuses on the development and prototyping of new technologies and capabilities to meet government needs that cannot be met as effectively by the government's existing in-house or contractor resources. An emphasis is on R&D to address emerging DoD technology areas. Program activities extend from fundamental investigations through design and field testing of prototype systems using new technologies. A strong emphasis is placed on the transition of systems and technology to the private sector. Lincoln Laboratory has been in existence for 73 years. On its 25th and 50th anniversaries, the Laboratory received the Secretary of Defense Medal for Outstanding Public Service in recognition of its distinguished technical innovation and scientific discoveries.

Table of Contents

Letter from the Director

For nearly 75 years, Lincoln Laboratory has prototyped and transitioned advanced technology and systems to keep our nation and service members safe. Developing innovative solutions requires a deep understanding of complex challenges, world-class expertise, and a culture of collaboration—all of which the Laboratory has rigorously cultivated since its founding.

In the following annual report, you will read about some of our recent critical contributions to national security and the wide-ranging impact we continue to have on the United States and the world.

- In space, our laser communications (lasercom) systems for NASA set a record for the fastest satellite downlink, demonstrated the first two-way space lasercom relay, and achieved the farthest lasercom link ever recorded. These breakthroughs are heralding a new era in satellite communications for defense and civil missions.
- The Missile Defense Agency selected the Laboratory to lead the Hypersonic and Ballistic Tracking Space Sensor science team. With government and industry collaborators, we are overseeing the planning of on-orbit experiments, collection of data, assessment of prototype satellites, and evaluation of constellation concepts.
- Artificial intelligence (AI) remains an enabling technology across mission areas. We applied AI to demonstrate autonomous piloting of a military aircraft, accelerate the design of materials, expedite disaster-response activities, and detect anomalous air tracks, among other applications.
- To ensure readiness for U.S. military bases, the Laboratory conducted control system, water, and energy resilience readiness exercises to reduce mission impacts caused by power outages or cyberattacks.
- As a central participant in the Microelectronics Commons program to expand U.S. leadership in microelectronics, we are pursuing several research projects leveraging the Laboratory's microelectronics fabrication facilities and bridging academia and industry.
- A cybersecurity module certified by the National Security Agency is accelerating the fielding of uncrewed systems. The module is being manufactured for use in U.S. Navy robots and can be adapted for various platforms.
- To support service member health, we prototyped and tested medical technologies to care for wounded soldiers in remote environments and to monitor for illness and fatigue.
- Advanced techniques are improving the accuracy of high-frequency over-the-horizon radar to provide persistent, wide-area surveillance at very long ranges.
- To the Department of Homeland Security, we delivered a low-cost chemical vapor sensor capable of remotely detecting and reporting the presence of chemical threats.
- The Laboratory delivered two space domain awareness (SDA) payloads integrated on Japanese satellites. We also delivered critical SDA tools to the National Space Defense Center to enable timely and effective decision support.
- Algorithms to remove interference in airborne moving-target-indication radar collections were implemented on an advanced tactical airborne sensor.
- Fifteen technologies received R&D 100 Awards, recognizing them among the year's most innovative products transitioned to use or made available in the marketplace.

In addition to developing new technology, we maintained a strong focus on mentoring the next generation of scientists and engineers. The Laboratory's integral relationship with MIT campus enabled impactful partnerships for research and workforce development. We also received recognition for our commitments to fostering a respectful workplace and operating in a secure environment.

All of these achievements are made possible by dedicated staff who bring an unwavering commitment to solving the urgent problems we tackle for the nation. In my first year as director, I have felt inspired every day by the excellence of this community and the important work we do together.

Sincerely,

Melissa Choi
Director

MIT Lincoln Laboratory

MISSION: TECHNOLOGY IN SUPPORT OF NATIONAL SECURITY

VISION

To be the nation's premier laboratory that develops advanced technology and system prototypes for national security problems

- To work in the most relevant and difficult technical areas
- To strive for highly effective program execution in all phases

STRATEGIC DIRECTIONS

- Continue evolving mission areas and programs
- Strengthen core technology programs
- Increase MIT campus/Lincoln Laboratory collaboration
- Strengthen technology transfer to acquisition, user, and commercial communities
- Find greater efficiencies and reduce overhead process
- Improve leverage through external relationships
- Enhance Laboratory facilities
- Enhance Laboratory community outreach and education

VALUES

How we approach our work

Integrity, Excellence, and Innovation

- We strive for the highest standards of integrity and excellence as we deliver technology in support of national security.
- Honoring Lincoln Laboratory's history, we believe interdisciplinary teams and a culture of collaboration drive research and development as we solve important problems in service to the nation.
- We take on bold endeavors with curiosity, ingenuity, humility, and dedication to our mission. We challenge our assumptions and accept the risk of failing as a critical part of innovation.
- As trusted stewards of government information and resources, we hold ourselves accountable to providing clear, accurate, and unbiased guidance to our sponsors and partners and using government resources efficiently and responsibly.
- We recognize the multidimensional impact of technology and our responsibility to conduct our research with the highest ethical standards.
- We challenge ourselves to face difficult facts, speak plainly about shortcomings in our systems, and overcome them.

How we interact with each other

Belonging, Respect, and Service

- We strive to make our community a welcoming place where everyone feels they belong and has the opportunity to thrive. We encourage work-life balance.
- We practice decency, kindness, empathy, and respectful dialogue. We promote psychological safety and strive to be transparent and worthy of each other's trust.
- We value accomplishments and potential over pedigree.
- We do not tolerate bad behavior or disrespect, especially on the basis of great accomplishment, talent, or power.
- We encourage service to our global, national, and local communities and take pride in creating opportunities for education and transfer of technology.
- We depend on contributions from every individual in every role to accomplish our mission.

MIT and Lincoln Laboratory Leadership

Massachusetts Institute of Technology

From left, **Cynthia Barnhart**, *Provost*; **Sally Kornbluth**, *President*; **Ian A. Waitz**, *Vice President for Research*

MIT Lincoln Laboratory

From left, **Justin J. Brooke**, **Robert D. Loynd**, **Asha Rajagopal**, **Chevalier P. Cleaves**, **Melissa G. Choi**, **Israel Soibelman**, **Heidi C. Perry**, **C. Scott Anderson**, **Marc N. Viera**

Organizational Changes

Melissa G. Choi

Director, Lincoln Laboratory

Melissa G. Choi joined Lincoln Laboratory as a technical staff member in the Advanced System Concepts Group in 1999. In 2006, she became assistant leader of the group before transitioning to assistant leader, then leader of the Systems and Analysis Group. Choi served as leader of the Active Optical Systems Group, after which she became assistant head of the Intelligence, Surveillance, and Reconnaissance (ISR) and Tactical Systems Division. In 2014, she was appointed head of the Homeland Protection and Air Traffic Control Division and subsequently helped establish the Humanitarian Assistance and Disaster Relief Systems Group. From 2019 to 2024, Choi served as assistant director of Lincoln Laboratory, overseeing five of the Laboratory's technical divisions and its Air Force–sponsored programs. In this role, she led the formation of the Laboratory's Civil Space Systems and Technology Office in 2023.

Over her career, she has maintained a longstanding commitment to mentoring and other initiatives that support the retention of high-quality staff. She served for six years on the Air Force Scientific Advisory Board, and was appointed to the DoD's Threat Reduction Advisory Committee. In both roles, she received awards for exceptional public service. Choi was appointed to her current role in July 2024.

Marc N. Viera

Assistant Director, Director's Office

Marc Viera joined Lincoln Laboratory in 2002, working on both red and blue team activities integrating systems analysis, hardware development, and countermeasure assessments. His technical expertise includes advanced infrared and radio-frequency systems; electronic warfare; integrated air defenses; and ISR and tactical system architectures. Viera served as leader of the Systems and Analysis Group from 2012 to 2014 and then as leader of the Advanced Capabilities and Systems Group from 2014 to 2015. In 2015, he joined the ISR and Tactical Systems Division as an assistant head and was promoted to division head in 2020. He led the establishment of new systems-of-systems architecture and assessment teams, new national workshops for government and industry leaders, and the rapid prototyping of novel capabilities, including micro–uncrewed aerial vehicle swarms. He is considered a national subject matter expert for ISR and tactical system technology and has served on multiple Defense Science Board studies. He was appointed to his current role on January 1, 2025.

D. Marshall Brenizer

Head, Space Systems and Technology Division

Upon joining the Laboratory in 2002, D. Marshall Brenizer contributed to the development of space surveillance technologies. He worked with the U.S. space community to examine and develop concepts for reducing vulnerabilities to space threats. He held several leadership roles in the Space Systems Analysis Group before his promotions to assistant head and associate head of the Space Systems and Technology Division in 2018 and 2019, respectively. He has guided the DoD's space strategy through the formation of the Space Protection Program, Space Security and Defense Program, and Space Warfare Analysis Center. His work has shaped the Laboratory's space security strategy and set the foundation for the nation's Space Force design. Brenizer was promoted to his current role in July 2024.

>> *Continues on page 6*

Pamela R. Evans

Assistant Head, Space Systems and Technology Division

Pamela R. Evans came to Lincoln Laboratory in 1995. After ten years of working in several groups, she was promoted to assistant leader of the Advanced Sensor Techniques Group, where she significantly expanded the exploration of capabilities in airborne foliage-penetration radar system design and space-based radar. Evans was promoted to associate leader and then leader of the ISR Systems and Architectures Group. She began leading development of system architectures for obscured target sensing, maritime domain awareness, and dismount detection. Under her leadership, the group's portfolio grew to include advanced sensor systems, platform survivability, electronic warfare, communications, and battle management. Evans has led national studies and the Laboratory's internally funded portfolio for integrated systems, and has served on the Air Force Scientific Advisory Board. She was promoted to her current role in November 2024.

Pablo I. Hopman

Assistant Head, Space Systems and Technology Division

In 2000, Pablo Hopman joined the Laboratory as technical staff in the Space Control Systems Group. In 2003, he transferred to the Advanced Space Systems and Concepts Group, and was promoted to senior staff in 2007 and assistant leader in 2008. He helped bring optical and camera technologies into systems for space situational awareness, space control, and airborne persistent surveillance. In several different group leadership roles from 2012 through 2018, Hopman led the development of critical detector technologies used across the Laboratory, and set up the TROPICS and SensorSat programs. Hopman left the Laboratory in 2020, but returned in 2022 as principal staff in the Space Systems and Technology Division, where he has contributed significantly to the strategic direction of the division. He was promoted to his current role in November 2024.

Livia M. Racz

Assistant Head, Advanced Technology Division

Livia Racz came to Lincoln Laboratory in 2015 and, within a few months, was promoted to assistant leader of the Quantum Information and Integrated Nanotechnologies Group. In 2017, she became assistant leader of the Advanced Materials and Microsystems Group, where she expanded the frontiers of advanced materials and their applications in micro- and nanosystems. In 2019, Racz was promoted to associate leader, at which time she managed the multidivisional Trusted and Assured Microelectronics program. She also began to build a stakeholder community around advanced materials and microsystems and helped the Intelligence Advanced Research Projects Activity craft their largest-ever program. She was promoted to group leader in 2021 and received the Laboratory's Technical Excellence Award in 2022. Racz was promoted to her current role in April 2024.

Mabel D. Ramirez

Assistant Head; Air, Missile, and Maritime Defense Technology Division

Mabel Ramirez joined Lincoln Laboratory in 2006 as a summer intern working on synthetic aperture radars and signal processing. In 2010, she became technical staff in the Intelligence, Test, and Evaluation Group. She was promoted to assistant leader in 2015, associate leader in 2017, and leader in 2018 of the Advanced Concepts and Technologies Group. Ramirez has led an advanced technology development and innovative research and development portfolio for the U.S. Navy, and virtual-environment joint cognitive operational research efforts, enabling foundational research in human–machine teaming technologies at the Laboratory. She received the Lincoln Laboratory Award for Leadership in Advancing Organizational Culture and was a Boston Business Journal Top 40 Under 40 honoree. Ramirez was promoted to her current role in December 2024.

M. Jalal Khan

Assistant Head, ISR and Tactical Systems Division

After joining the Laboratory in 2004, Jalal Khan played key leadership roles in a series of operationally field-tested aircraft systems, including the ALIRT wide-area mapping system and the MACHETE foliage-penetrating ladar system. He was promoted to assistant leader and leader of the Active Optical Systems Group in 2011 and 2015, respectively. He has continued to oversee the development of wide-area 3D ladar systems, including one that demonstrates world-record long-range 3D imaging capabilities. Under his leadership, the group has been recognized with multiple R&D 100 Awards and Laboratory Team Awards. Khan is a member of the Optical Systems Line committee and co-leads the Technology Committee for the Civil Space Systems and Technology Office. He was promoted to his current role in January 2024.

MIT Lincoln Laboratory Fellow

The Fellow position recognizes the Laboratory's strongest technical talent for their outstanding contributions over many years.

Grant H. Stokes

Grant Stokes joined the Surveillance Techniques Group in 1989 and contributed to ground system development and on-orbit testing for the Space-Based Visible sensor program. He held several leadership roles and developed programs in space debris and asteroid detection. Stokes was promoted to assistant head in 1999 and associate head in 2001 of the Space Systems and Technology Division. He developed the Lincoln Near-Earth Asteroid Research program, which became the world's premier asteroid search capability, discovering more 1 km and larger near-Earth asteroids than any other search program. In 2007, he supervised the demonstration of the first space-based space-surveillance system to the Air Force, and initiated programs to develop next-generation technology for space situational awareness.

He co-chaired the 2018 Defense Science Board Space Resilience Task Force and partnered with Space Force and Space Command to analyze the evolution of space to a contested domain. Stokes was honored with the Air Force Meritorious Civilian Service Award for his four years of service to the Air Force Science Advisory Board. He was appointed an IEEE Fellow in 2010, was elected to the National Academy of Engineering in 2016, and became an AIAA Fellow in 2022, all for innovating new systems and architectures for space situational awareness and discovery of near-Earth asteroids.

Scott B. Van Broekhoven

Assistant Head, ISR and Tactical Systems Division
Director, MIT Lincoln Laboratory Beaver Works Center

Scott Van Broekhoven joined the Optical Systems Engineering Group in 2001 and held several leadership roles in various groups over a decade. In 2013, he was promoted to assistant leader of the Rapid Prototyping Group and received an Early Career Technical Achievement Award in 2014. In 2015, Van Broekhoven became the founding leader of the Energy Systems Group. In 2017, he became leader of the Advanced Capabilities and Systems Group, which he led until his promotion to assistant head of the ISR and Tactical Systems Division in January 2024.

Van Broekhoven has been heavily involved in Beaver Works since its founding more than 10 years ago. He worked closely with faculty in the MIT AeroAstro and Mechanical Engineering Departments on more than a dozen capstone classes for MIT and recently served as the academic co-director of the Beaver Works Summer Institute prior to his appointment as director. He was promoted to director of MIT Lincoln Laboratory Beaver Works Center in July 2024.

Derek W. Jones

Chief Security Officer, Security Services Department

Derek Jones joined the Laboratory in 2003 and assumed increasing levels of responsibility. In 2011, as manager of government security and operations, he was responsible for the Laboratory's collateral industrial security program and made significant improvements to the Personnel Security Services Center, Insider Threat Program, Education and Awareness Programs, and Visitor Services Center. In 2019, as assistant head of the Security Services Department, he provided guidance to the Laboratory's industrial security and special programs. He was appointed deputy chief security officer in 2021 and acting chief security officer in 2023. He was promoted to his current role in May 2024.

Scott J. Mancini

Chief Information Security Officer, Security Services Department

Scott Mancini joined the Laboratory in 2008. In 2010, he was promoted to compliance and forensics team leader, establishing the Laboratory's Forensic Analysis Center. He was appointed assistant head of the Security Services Department in 2019, and began serving as the acting chief information security officer in 2023. Mancini leads the Laboratory's Security Assessment and Authorization program and has taught the "Decision Making in Critical Infrastructure Protection" course at Northeastern University. He was promoted to his current role in May 2024.

Deep-Space Camera Achieves Farthest Laser Communications Link Yet

The transmission traveled more than 250 million miles from an instrument incorporating a Laboratory-built camera aboard NASA's Psyche spacecraft.

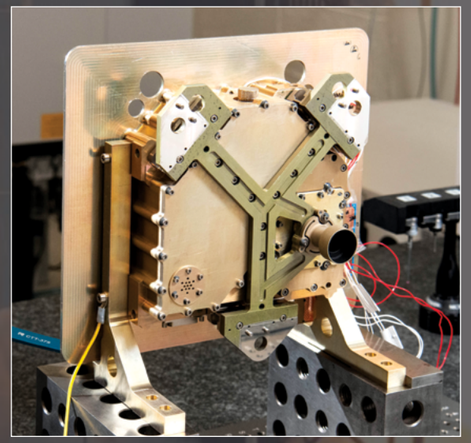
In June 2024, the Hale Telescope at Caltech's Palomar Observatory in San Diego County, California, received a transmission from the Deep Space Optical Communications (DSOC) system—an instrument aboard NASA's Psyche spacecraft, which is managed by the Jet Propulsion Laboratory. The data had traveled 250 million miles, from Mars's furthest distance from Earth, at a rate of 8.3 megabits per second (Mbps). This transmission represents the farthest high-rate laser communications (lasercom) link ever recorded, and its success was one of many records set during the first year of the satellite's operation.

The Psyche spacecraft is en route to an asteroid located between Mars and Jupiter to study its metal-rich composition. The DSOC demonstration mission is serving as a pathfinder for future high-speed communications between Earth and Mars. A key piece of this demonstration is the DSOC system's Photon-Counting Camera (PCC), built by Lincoln Laboratory.

The PCC serves several functions within the DSOC system. One is to facilitate the system's pointing, acquisition, and tracking capabilities. Compared to radio-frequency (RF) systems, lasercom systems can achieve higher data rates because they transmit data in a narrower beam. A narrower beam permits more power (and therefore data) to hit the receiver, but the beam must be aimed precisely; otherwise, it may miss the receiver entirely.

The ground portion of the DSOC system includes a powerful laser that acts as a beacon to the Psyche spacecraft. However, Psyche is so far away that much less than a trillionth of its light makes it to the spacecraft.

In order to see this dim light and distinguish it from the surrounding stars, the PCC uses a Laboratory-developed technology called Geiger-mode avalanche photodiodes (GmAPDs). The GmAPDs allow the camera's pixels to see individual photons and time their arrival to each pixel up to a billionth of a second. The timing is important because the ground beacon blinks on and off in a prearranged pattern. By measuring the beacon blink pattern, the PCC can distinguish the beacon from other sources of light. The PCC is also responsible for receiving information from that beacon.



The PCC, above, is mounted onto the DSOC system using a Y-shaped bracket. The tube connected to the Y is a baffle that protects the GmAPD array from stray light emitted from within the spacecraft. Photo: Lincoln Laboratory

The Psyche spacecraft's Flight Laser Terminal contains the Deep Space Optical Communications System Photon-Counting Camera, bottom right, built by Lincoln Laboratory. Photo: NASA

The PCC's final function is to measure the pointing of the downlink (the light that sends information from the spacecraft back to Earth) to the ground terminal. Aiming the downlink back to Earth is no easy task, as the spacecraft is not only millions of miles away from the Earth but also moving very fast. This combination of speed and distance means that the beacon is not where the Earth seems to be at any given time, but rather where it was 20 minutes ago. The PCC corrects for this movement to point the downlink at the correct location.

In addition to the DSOC's record-setting communications link distance, other important successes include establishing a 267 Mbps downlink (which is about the rate of a good, high-speed internet connection) from 33 million miles and a 4.7-terabit downlink in a single pass. Uplink commands were successfully sent to the spacecraft in the daytime and received by the DSOC beyond Mars, all the way out to 288 million miles. In addition, the DSOC demonstrated a new mode of lasercom by combining the signal from three separate ground telescopes in order to achieve a 50 Mbps downlink at 111 million miles. Although the original mission called for sending only pre-saved test data, the DSOC flight terminal ultimately sent system and spacecraft data to Earth, providing valuable diagnostics that could not have been sent using the baseline RF communications system.

The ability to send and receive data quickly over vast distances is a prerequisite for deep-space crewed and uncrewed missions. Currently, planetary mission planners design instruments and data collection for relatively low-rate RF communications systems. These missions are planned for a decade or more and then require another decade to carry out, making each opportunity rare and costly. Lasercom from deep space can increase the amount researchers can learn from each mission by at least tenfold.

The PCC is part of a growing number of Laboratory technologies deployed for civil space applications that benefit the nation beyond advancing national security. It is one of several other recent successful lasercom demonstrations, which together provide a broad set of options for sending and receiving data in future space missions.

NASA's Psyche spacecraft, background image, launched in October 2023 on a SpaceX Falcon Heavy rocket from the Kennedy Space Center in Florida. Photo: NASA/Aubrey Gemignani

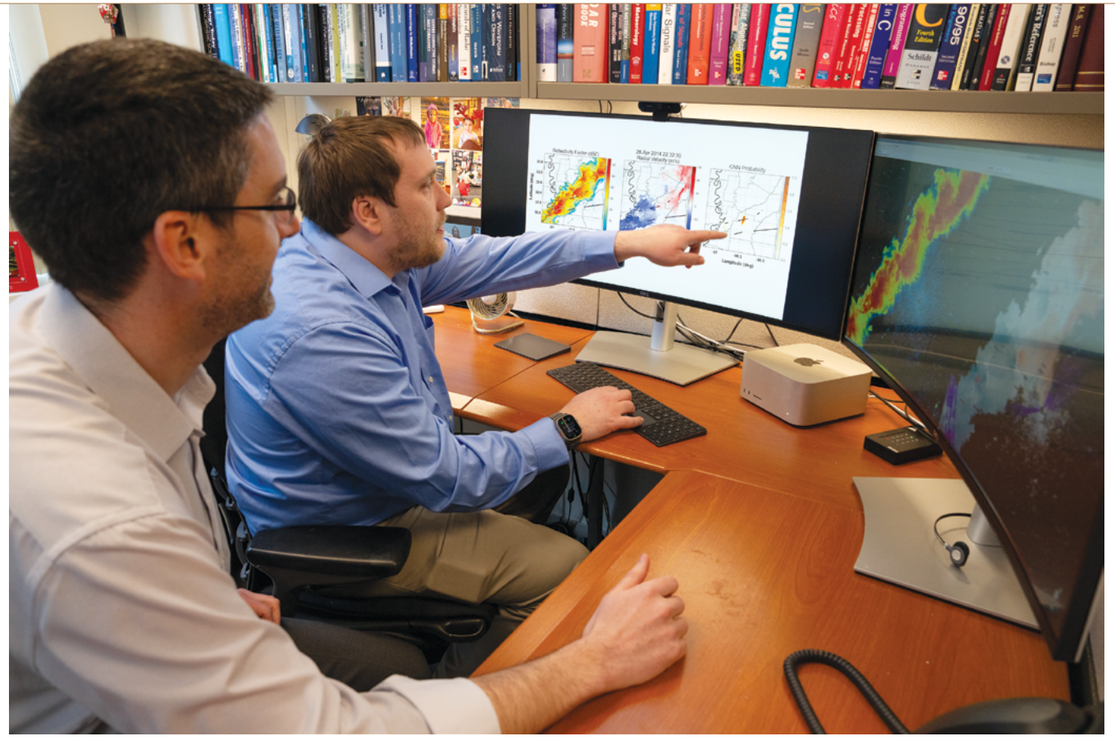
A tornado touches down in Hildreth, Nebraska. Photo: NOAA Weather in Focus Photo Contest 2015, Ken Engquist

A Dataset and Deep Learning Carve Paths to Tornado Detection

The open-source TorNet dataset will allow researchers to develop models that might help improve the accuracy of tornado warnings.

Tornadoes are one of the most difficult weather phenomena to forecast. The exact conditions that cause a tornado to form remain unclear; once formed, a tornado is too low to the ground to be detected by radar. Forecasters must look for tornado indications within a thunderstorm's large, rotating updraft. Yet one storm that spawns a tornado may look nearly identical to one that does not. Because of this uncertainty, about 70% of tornado warnings are false alarms, diminishing the public's trust in warnings and urgency to take cover in regions most affected by these events.

To improve tornado detection, Lincoln Laboratory researchers are turning to artificial intelligence (AI). They want to take advantage of the plethora of weather radar data available today, both to develop AI models and empower the weather and data-science communities to tackle this problem. Such models might detect tornadoes more accurately than current methods or discover new precursors to improve forecasting.



Mark Veillette, left, and James Kurdzo compiled TorNet, an open-source dataset containing thousands of radar images, including the examples shown on the screen, that depict tornadoes and severe storms. The dataset can serve as a benchmark to develop tornado-detecting AI algorithms.

To enable this research, a team led by James Kurdzo and Mark Veillette curated a large weather radar dataset, called TorNet. The dataset contains more than 200,000 radar samples taken from U.S. storms over the past 10 years. Each sample is a snapshot in time, containing radar images depicting different variables, such as reflectivity factor (indicating precipitation intensity) or radial velocity (indicating wind speed and direction).

The samples fall into three categories: tornadic-storm samples, including every confirmed tornado from the past decade; false-alarm samples, representing storms with issued warnings but no tornado development; and non-tornadic samples in environments that were generally supportive of severe storms and tornadoes. These categories make up 7%, 32%, and 61% of the dataset, respectively. Because tornadoes are rare events within the entire corpus of weather radar observations, the researchers had to strike a realistic balance of tornadic and non-tornadic samples so that a model trained on the data would not falsely over-detect tornadoes.

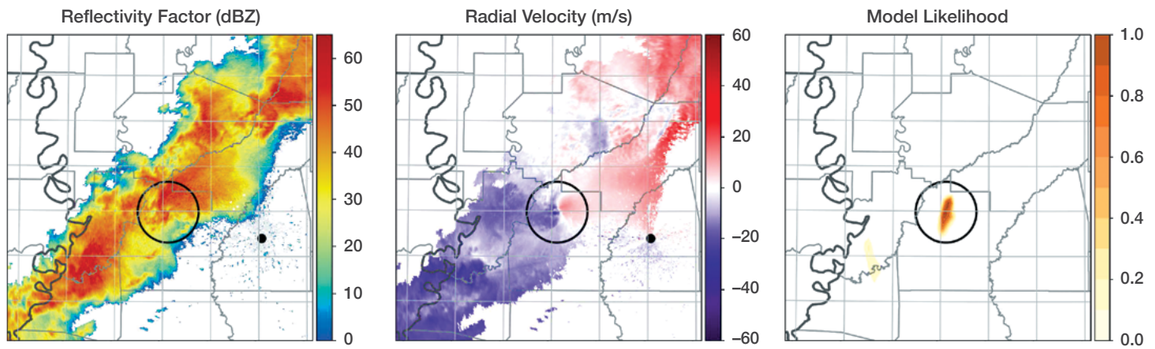
Using TorNet, the researchers developed baseline AI models. They were eager to apply deep learning, a form of AI that excels at processing visual data. Deep learning models can automatically extract features from data, in contrast to other AI approaches that require humans to manually define features. The researchers wanted to see if deep learning could rediscover features that meteorologists normally look for in tornadoes or even uncover overlooked ones.

Their results were promising: the deep learning model performed similar to or better than all tornado-detecting algorithms reported in the literature. The trained algorithm correctly classified 50% of weaker EF-1 tornadoes and more than 85% of tornadoes rated EF-2 or higher, which make up the most devastating and costly occurrences of these storms. They also developed and evaluated two other types of AI models and one traditional model to compare against. The source code and parameters of these models were released publicly so that other groups could build on this work.

Most importantly, the researchers released TorNet as an open-source benchmark dataset: a carefully curated, public data repository shared with the world to accelerate the pace of research and development. Benchmark datasets allow separate research teams to easily compare results, and they help to establish trust and transparency in AI models because the data used to train them are public. While such benchmarks are growing in popularity within the field of meteorology, a tornado-focused benchmark dataset had not previously existed.

TorNet could be augmented with other data sources, such as satellite imagery or lightning maps, to further improve the accuracy of AI models trained on it. For forecasters, AI assistance could be especially useful in the future as technology advances, networks grow denser, and data refresh rates improve. Because deep learning can process huge amounts of data quickly, it could be well-suited for monitoring radar returns in real time, alongside humans.

The team feels hopeful that AI could one day lower the false-alarm rate of tornado warnings, in turn diminishing the "cry wolf" effect. For people in the path of any one of the approximately 1,200 tornadoes to occur each year, trust in a warning could mean the difference between life and death.



This figure depicts an accurate tornado detection by the Laboratory's deep learning model trained on the TorNet dataset. The left and middle panels show radar images (reflectivity factor and radial velocity, respectively) of a Mississippi storm on April 28, 2014. The circle in the middle of the images indicates the location of a confirmed tornado. The deep learning model indicated a very high likelihood of a tornado in the same location, as seen in the right panel.

MISSION AREAS 13

Eric Morgan, left, and Ryan Wiechens of the Energy Systems Group ready a hydrokinetic turbine for deployment in a river. The turbine generates electricity in remote areas using the power of flowing water.

Space Systems and Technology

Ensuring the effectiveness of the nation's space enterprise by designing, prototyping, operating, and assessing systems to provide space domain awareness, resilient space capability, space control, and associated cross-domain battle management

Leadership

D. Marshall Brenizer
Division Head

Gregory D. Berthiaume
Asst. Division Head

Timothy D. Hall
Asst. Division Head

Grant H. Stokes
Laboratory Fellow

Lawrence M. Candell
Principal Staff

The SACHI space domain awareness sensor payloads are hosted aboard two Japanese satellites launching in 2025. Each payload, one of which is pictured above with the U.S. and Japanese technical integration teams, measures 45 × 31 × 19 inches and weighs 154 pounds.

Principal 2024 Accomplishments

- Through a Cooperative Research and Development Agreement with the local company Tomorrow.io, four identical satellites were launched. These high-performance satellites provide passive microwave sounding and imagery data of tropical cyclones comparable to that of state-of-the-art operational systems, but at about 100× reduced size, weight, and power for each unit and at about 2% of the total system cost.

- For the Situational Awareness Camera Hosted Instrument (SACHI) program, the Laboratory rapidly developed and delivered two identical space domain awareness (SDA) sensors to Japan. Through its significant onboard data processing capabilities, SACHI aims to increase SDA capabilities across Eurasia. The sensors will launch in 2025.

- The Laboratory delivered critical SDA information and tools to the National Space Defense Center in Colorado and the Combined Space Operations Center in California. For these centers, the Laboratory modernized networking, data architecture, and processing capabilities of new and legacy space surveillance sensors to improve the timeliness of tactical missions. The Laboratory also built prototypes of net-centric data libraries that enabled U.S. Space Force operators to leverage an array of DoD and commercial SDA data, and applied machine learning and artificial intelligence to SDA data to enable timely and effective decision support for the space domain.

- Laboratory researchers continued advising and engaging with the national space community to help identify the most pressing problems. The Laboratory's cross-domain assessments to ensure survivable architectures and research to identify gaps in U.S. sensor capabilities supported the Space Warfighting Analysis Center, Space Security and Defense Program, Space Systems Command, and other organizations. As part of the U.S. Department of the Air Force Red Team, the Laboratory informed cross-domain and space survivability needs, prototyped and tested passive radio-frequency ground systems, and developed other ground-based space sensors.

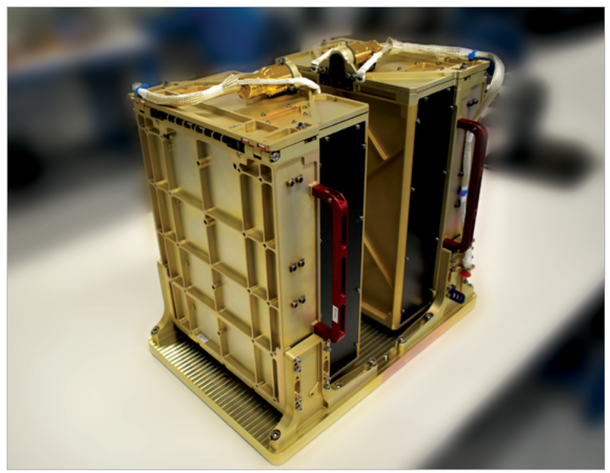
Future Outlook

With the DoD's growing reliance on space systems to deliver tactical effects, the resilience of the nation's space enterprise is a significant national security issue. Addressing this issue will require new architectures with integrated multidomain capabilities, supported by SDA and space responses on tactical timelines.

Laboratory focuses are sensing, information extraction and integration, decision support, and new architectures for integrated multidomain missions. Leveraging progress in microelectronics and commercial space, the Laboratory will develop and prototype novel systems and end-to-end architectures critical to shaping a future space capability. The Laboratory will also advance a net-centric architecture approach capable of discovering and incorporating new data sources and services on short timelines. This approach will ensure that the nation's space enterprise can continuously adapt to meet evolving mission needs.

Tropical Storm Monitoring

In August and December 2024, two pairs of satellites containing Laboratory-developed compact microwave sounder technology were launched into space; the pair launched in August is pictured at right. These four satellites are the first of a planned 18-satellite constellation that is expected to provide a global revisit rate of less than one hour. Made from commercially available CubeSat hardware, the complete satellite constellation will keep a near-constant watch over tropical storms. This careful monitoring will dramatically improve hurricane forecasting, informing evacuation and rescue operations and ultimately saving lives. The Laboratory first developed the sounder technology as part of the NASA-funded TROPICS program.



Air, Missile, and Maritime Defense Technology

Advancing defense of the homeland, deployed forces, and allies against air and missile threats by enabling robust deterrence, assessing system architectures, prototyping pathfinder technologies, and demonstrating integrated systems for airborne, surface, and undersea defenses

Leadership

Katherine A. Rink
Division Head

William J. Donnelly III
Asst. Division Head

Aryeh Feder
Asst. Division Head

Sung-Hyun Son
Asst. Division Head

David Whelihan flies a drone to retrieve data from a Laboratory-developed integrated sensor node deployed in the Arctic during Operation Ice Camp 2024. The node is intended to become part of a widespread sea-ice monitoring network.

Principal 2024 Accomplishments

- The Laboratory advanced techniques to improve the real-time metric accuracy of high-frequency (HF) over-the-horizon radar. A team recently collected an extensive dataset from a well-instrumented radar and a collection of spatially diverse mid-latitude HF transponders.
- After completing prototyping of a new airborne RF sensor, the Laboratory flight-tested the prototype on its Gulfstream IV platform to evaluate novel sensor concepts and waveforms.
- The Laboratory's FTX-23 flight-test countermeasure package was instrumental in creating one of the most complicated target scenes ever presented to the Aegis Weapon System.
- To improve the U.S. Navy's acoustic intelligence enterprise, the Laboratory provided calibrated beamforming, tracking, and localization algorithms. The Laboratory also continued leading the development of a modern knowledge management system to secure and process the vast amount of acoustic data.
- Hypersonic interceptor technology is critical for the nation's counter-hypersonic capabilities. Sponsored by the Missile Defense Agency (MDA), the Laboratory prototyped and tested novel seeker sensors in relevant hypersonic environments.
- The MDA selected the Laboratory to lead the Hypersonic and Ballistic Tracking Space Sensor science team. With collaborators from the government, other federally funded research and development centers, university-affiliated research centers, and industry, the Laboratory will oversee the planning of on-orbit experiments, collection of mission-relevant data, performance assessment of prototype satellites, and evaluation of future constellation concepts.
- On coordinated U.S. Coast Guard vessels in the Boston area, the Laboratory conducted field-test imaging with its recently completed multicamera digital infrared imager test bed to further advance capabilities in maritime target detection and classification.

Future Outlook

Great-power competition has increased national focus on strategic deterrence and power projection, while advancing missile threats necessitate fundamental shifts to defense architectures. The Laboratory is developing sensing technologies to enable long-range engagements and driving the integration of air and missile defense.

Dynamic multidomain operations offer a competitive national advantage. The Laboratory is prototyping concepts and forging collaborations that cross traditional mission areas.

The Laboratory is developing AI and autonomy technology to address growing decision complexity.

The Laboratory is executing a portfolio to understand the pacing hypersonics threat to our nation and allies, define future architectures, and mitigate technical risks.

Low-Cost Interceptor Missile

The United States lacks a mass-producible, low-cost (<$1,000/unit) interceptor missile to defeat inexpensive one-way attack drones currently depleting U.S. stockpiles of exquisite interceptors. Combining an original 3D-printed reconfigurable airframe with commercially available components and mature DoD software, the Low-Cost Reconfigurable Weapon (L-CROW) is the world's smallest and least expensive short-range, platform-agnostic, rocket-propelled, fire-and-forget, electro-optically-guided, surface-to-air interceptor missile. Here, at Turner Drop Zone at U.S. Army Fort Devens Reserve Force Training Area, Lenny Urbano, left, and Robert Palladino attach L-CROW to a launch rail using a custom-designed 3D-printed pair of fly-away launch buttons. These buttons significantly reduce atmospheric drag and enable L-CROW to maintain high speed.

Communication Systems

Advancing communication capabilities for national security and space exploration through technology development in satellite communications, robust networking, laser communications (lasercom), quantum systems, and agile spectrum operations

Leadership

Thomas G. Macdonald
Division Head

James Ward
Assoc. Division Head

Michele A. Schuman
Asst. Division Head

The Laboratory's Integrated Lasercom Relay Demonstration (LCRD) Low Earth Orbit User Modem and Amplifier Terminal (ILLUMA-T) released from the International Space Station in June 2024 after six months of testing. ILLUMA-T and LCRD demonstrated NASA's first in-space two-way lasercom relay.

Principal 2024 Accomplishments

- Lincoln Laboratory developed methods to harness 5G cellular networking components for DoD usage in contested spectral environments where interference is prevalent.
- On-orbit checkout of the Enhanced Polar System–Recapitalization satellite constellation employed Laboratory-developed ground terminals in Alaska.
- A Laboratory team demonstrated ultrahigh-efficiency coupling of optical fibers to quantum memory modules for low-loss quantum memory operation. These memory modules were incorporated into the Boston-area quantum network test bed for system-level characterization of their performance.
- For directional communications on airborne platforms, the Laboratory designed and prototyped a modular phased array system that leverages emerging commercial chipsets to reduce cost.
- With U.S. Air Force partners during the Emerald Flag exercise, the Laboratory demonstrated advanced communication and networking technologies. Platforms enabled by these technologies dynamically disseminated mission-relevant data across disparate networks, increasing shared situational awareness and connecting data producers with consumers.
- The Laboratory delivered the first unit of the next-generation Strategic Test Terminal, which will facilitate development of the Evolved Strategic SATCOM system for nuclear command, control, and communications.
- Technology to support multi-access laser communications via frequency-division multiplexing completed a system concept review.
- In September 2024, the TeraByte InfraRed Delivery (TBIRD) demonstration completed its two-year mission. Reaching data rates of 200 Gbps, the Laboratory-developed TBIRD payload set the world record for the fastest satellite downlink from space using lasercom.

Future Outlook

Laser communications systems will provide high-data-rate communications between space and ground, enabling high-definition videoconferencing and large-volume data transmission for NASA's crewed mission to the Moon in 2025.

Architectures for narrowband and disadvantaged-user communications will be developed to inform the future of ultrahigh-frequency SATCOM and to assess the military utility of emerging commercial 5G space network systems.

New communications waveforms and networking concepts will be required to create a networked space architecture in support of the U.S. Space Force. This network will enable real-time control of and integrated operations between space systems as well as dynamic data sharing between space and theater platforms.

Phased Array System

The Laboratory prototyped and demonstrated a phased array system—shown at right with Jason Davies, inset, configuring the array for an over-the-air test—that improves the range and reliability of existing DoD field radios. The array system is designed to use low-cost wire antennas that can be rapidly relocated as needed. A flexible software architecture allows for translation between different radios and protocols, further enhancing interoperability across the military services.

Cyber Security and Information Sciences

Conducting research, development, and evaluation of cyber components and systems, and developing solutions for processing large, high-dimensional datasets acquired from diverse sources, including speech, imagery, text, and network traffic

Leadership

Stephen B. Rejto
Division Head

Marc A. Zissman
Assoc. Division Head

Jeffrey C. Gottschalk
Asst. Division Head

Joseph P. Campbell
Laboratory Fellow

Jeremy Kepner
Laboratory Fellow

The Collaborative Autonomy in Competitive Environments team stands in front of an X-62 aircraft at Edwards Air Force Base. The aircraft successfully flight-tested AI autonomy, enabled by Laboratory-enhanced algorithms, as part of the DARPA Air Combat Evolution program.

Principal 2024 Accomplishments

- The Laboratory researched, developed, and field-tested new emitter-identification technologies, employing artificial intelligence (AI) algorithms, to improve own-force situational awareness.
- The Lincoln Laboratory Supercomputing Center (LLSC) played a critical role in training AI models used to demonstrate breakthrough air-to-air capabilities in the X-62 aircraft as part of the Defense Advanced Research Projects Agency (DARPA) Air Combat Evolution program.
- For the U.S. Cyber Command AI Task force, the Laboratory established a rapid-capability team that transitioned AI-enabled technologies.
- The Laboratory developed technologies that enable cyber operators to proactively defend critical Internet of Things devices through automated collection and analysis of device data.
- The Laboratory designed and prototyped noninvasive, data-centric, cryptographically backed data integrity protections on air assets and demonstrated a prototype in a major multidomain DoD exercise.
- The complexity of gaining National Security Agency (NSA) certification for radios in uncrewed systems can delay their fielding. To address this problem, the Laboratory developed an NSA-certified security module that is easy to manage and use in various settings. The module is being manufactured for use in U.S. Navy explosive ordnance disposal robots.
- The Laboratory prototyped a cryptographic wrapper to enable fine-grained access control between bridged networks. This technology could provide a data-centric replacement for today's cumbersome cross-domain solution and lengthy approval process.
- The Laboratory tested and deployed to mission networks advanced natural language processing and AI-powered methods to enhance analyst capabilities at the Joint Warfare Analysis Center.

Future Outlook

The Laboratory will research and develop new signals intelligence capabilities for contested environments to improve situational awareness of U.S. deployed forces.

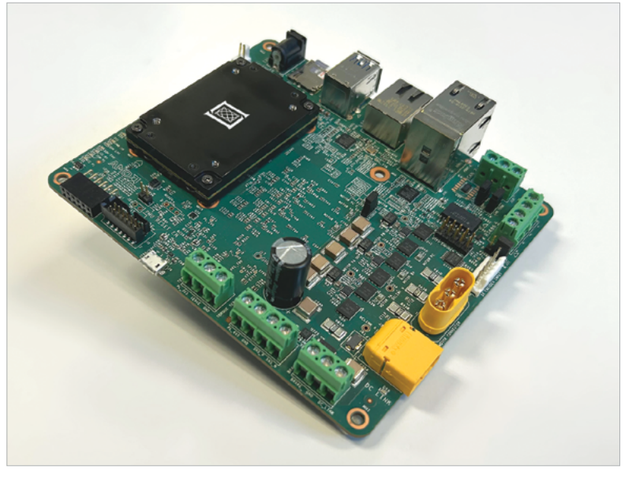
To help defend the nation's most critical AI systems, the Laboratory is standing up a world-class AI assurance team in collaboration with the National Security Agency's AI Security Center.

The Laboratory will advance technologies for hardening mission system software by automatically removing attack surfaces while maintaining compatibility and usability.

The LLSC will continue to deploy world-class supercomputers to enable AI, cyber-autonomous systems, and physical-simulation research.

Securing Classified Data in Space

Biotite, a collaborative effort between the DoD and the Laboratory, is a high-assurance software Space Internet Protocol Encryptor (SIPE) solution. It achieved a High-Assurance Internet Protocol Encryptor–interoperability milestone, which was successfully demonstrated to DoD partners. Biotite-SIPE is envisioned to provide a much-needed, software-based encryption solution for protecting classified data on small satellites and other size, weight, and power–constrained platforms. Biotite-SIPE leverages Magnetite, the Laboratory's secure-by-design, real-time operating system for securing embedded devices. It is developed in the Rust programming language that runs on top of the formally verified microkernel, seL4. At right is a compact hardware module running Biotite.



ISR Systems and Technology

Conducting research and development in advanced sensing, signal and image processing, decision support technology, and high-performance embedded computing to enhance capabilities in intelligence, surveillance, and reconnaissance

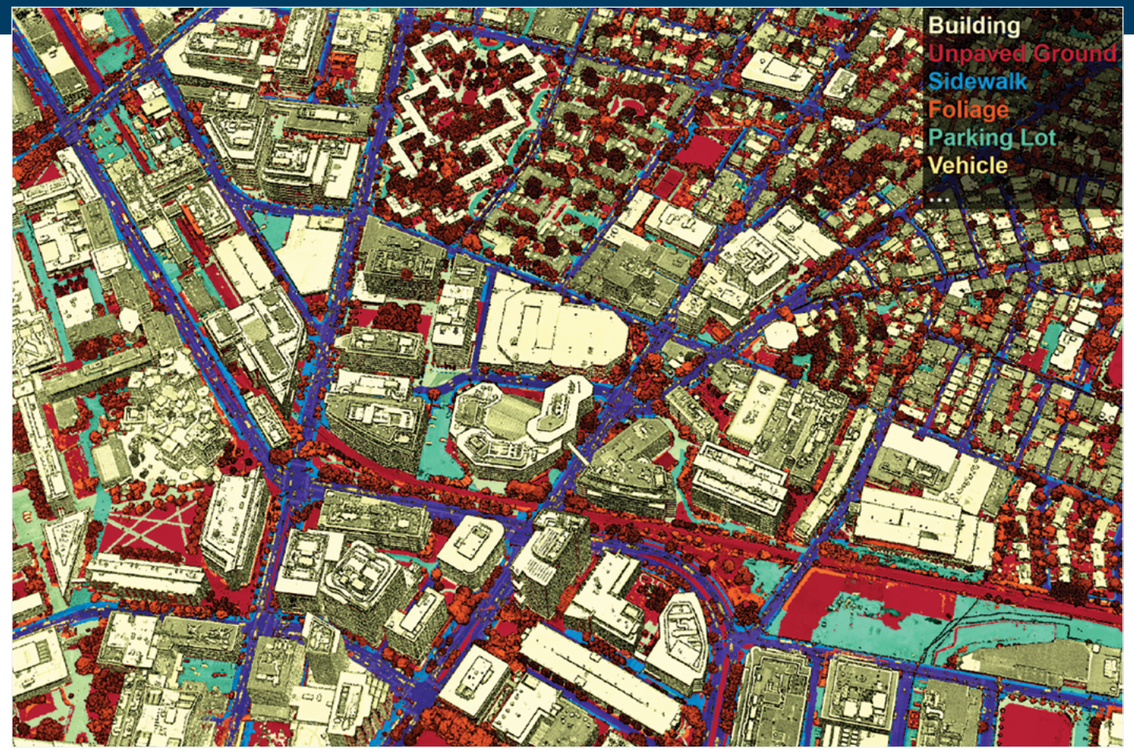
Leadership

Marc N. Viera
Division Head

Jalal Khan
Asst. Division Head

Daniel J. Ripin
Asst. Division Head

Scott B. Van Broekhoven
Asst. Division Head



The Laboratory's hierarchical context-based convolution neural network was used to perform automatic lidar semantic scene segmentation of Cambridge, Massachusetts.

Principal 2024 Accomplishments

- New concepts for ISR and air dominance were developed to meet future mission needs. Detailed modeling and systems analyses examined the potential impact of advanced technologies and innovative system-of-systems architectures, with a focus on joint-service and multidomain capabilities for contested environments.
- Laboratory researchers matured statistical methods to identify and remove interference in airborne moving-target-indication radar collections. Leveraging a library of previously collected data, the researchers developed, tested, and tuned algorithms, transitioning them to a contractor for implementation on an advanced tactical airborne sensor.
- The Laboratory supported DoD assessments of future counter-ISR architectures and evaluated advanced technologies for countering foreign ISR systems. The work seeks to define effective strategies and roadmaps for acquiring and employing advanced systems to protect U.S. forces.
- Through a program funded by the National Geospatial-Intelligence Agency, the Laboratory developed prototype software, now transferred to the U.S. government, that estimates the orientation of high-interest objects by using synthetic aperture radar imagery.
- The Laboratory's neural network–based automated scene classification software for lidar achieved a 15% increase in accuracy over existing state-of-the-art algorithms.
- A space-hardened lidar brassboard developed for a future NASA deep-space mission successfully passed ground testing at the Laboratory.
- Engineers rapidly prototyped and wrote algorithms for an acoustic array part of a trip-line system for air defense awareness. Four such systems were transitioned to U.S. Air Forces in Europe and demonstrated at Ramstein Air Base in Germany with various military aircraft.

Future Outlook

The Laboratory will continue to progress concepts that enable revolutionary ISR capabilities through the development of innovative algorithms, insertion of advanced technology, and integration of distributed sensing platforms.

Novel active and passive surveillance systems will be matured and transitioned to operations in currently critical theaters, including the Indo-Pacific.

A foliage-penetrating ground-moving-target-indicator coherent lidar has undergone initial field testing and will be further developed to support future U.S. defense missions.

The Laboratory will continue to participate in unique field-data collection campaigns to help develop and demonstrate state-of-the-art capabilities for the nation.

Radar and Communications at Millimeter Wavelengths

Lincoln Laboratory's Wideband Selective Propagation Radar (WiSPR), a dual-function millimeter-wave radar and communications platform, recently underwent successful testing at a U.S. Army test facility. Developed for the Army's Rapid Capabilities and Critical Technologies Office, WiSPR leverages advanced RF integrated circuits and a compact digital signal processing architecture to support the Army Modernization Strategy. This innovative design delivers enhanced capabilities in a small form factor. Here, Ryan Walton, left, and Ryan Lewis prepare WiSPR for the demonstration.

Tactical Systems

Improving the development of tactical air and counterterrorism systems through systems analysis to assess the impact of technologies on real-world scenarios; rapidly developing prototype systems; and conducting precise instrumented testing of systems

Leadership

Marc N. Viera
Division Head

Jalal Khan
Asst. Division Head

Daniel J. Ripin
Asst. Division Head

Scott B. Van Broekhoven
Asst. Division Head

Janet T. Hallett
Group Leader

Emily E. Lesser
Group Leader

The Small Inexpensive Counter Air (SICA) program demonstrated drone capabilities at an event hosted by the DoD. Each SICA drone, shown above, is estimated to cost less than $7,000 and uses a Laboratory-developed low-cost sensor to provide defense against one-way attack drones.

Principal 2024 Accomplishments

- To U.S. Air Force senior leadership, the Laboratory delivered a study on the viability of long-range kill chains and the operational impact of sensors to enable them. The study's recommendations will support future technology development.
- Laboratory staff evaluated concepts for air dominance, including next-generation fighters, uncrewed autonomous systems, and protection for aerial support capabilities. Results were shared with congressional members and Air Force senior leadership to inform near-term and future acquisition decisions.
- For the Department of the Air Force (DAF) Program Executive Office for Command, Control, Communications and Battle Management, the Laboratory conducted systems analyses and technical assessments of battle management and communications architecture needs and solutions to guide DAF BATTLE NETWORK design, investment, and experimentation.
- Compact, lightweight, and low-power battle management, sensing, and communications nodes can be adapted for multiple mission objectives in austere, denied environments. A Laboratory team developed a prototype portable node and demonstrated this node at the Emerald Flag 24-3 test event, held at Eglin Air Force Base in Florida. The node will help shape future Air Force design and acquisition decisions.
- Laboratory researchers fielded a new vision-based navigation technology that enables small uncrewed aerial vehicles to navigate safely in GPS-denied environments. Using onboard cameras and artificial intelligence–driven algorithms, the technology generates position and orientation estimates in real time. A custom-developed application combines the navigation estimates over large areas to support complex mission planning.

Future Outlook

Lincoln Laboratory researchers will continue to conduct systems analyses, laboratory testing, and flight-system data collections that inform assessments of the performance and limitations of Air Force aircraft capabilities against current and future threats. These assessments include investigations of missile systems, electronic attack and protection, and radio-frequency and advanced infrared kill chain strategies. As adversaries move to increasingly longer-range kills chains, the United States will need to develop methods to counter such threats in order to maintain air superiority.

The Laboratory will continue to leverage capabilities across the services by developing advanced command and control nodes that manage resources and deliver information to dispersed users. Researchers will also prototype disruptive tactical capabilities, including low-cost autonomous systems.

Gimballed Radiometric Imaging Pod

Recently, Lincoln Laboratory modified the U.S. Department of the Air Force Red Team's newest airborne test bed, a Gulfstream IV-SP, with a centerline pylon that enables the aircraft to carry large sensors to support flight testing for a range of DoD programs. These flight tests evaluate both the effectiveness and functionality of the programs' systems, drive solutions to identify capability gaps, and feed data into detailed systems analyses. Shown at right, a new airborne sensor is currently being integrated onto the platform and undergoing flight tests in preparation for future campaigns to enhance understanding of advanced airborne phenomenology.

Advanced Technology

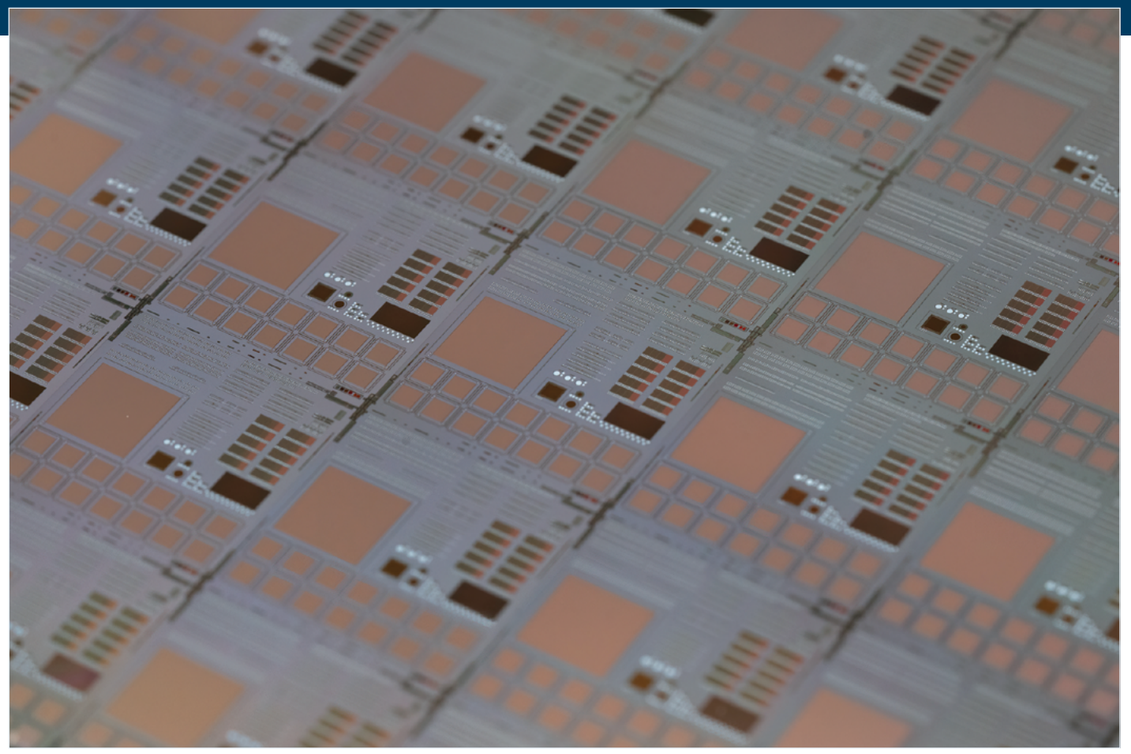
Leveraging solid-state electronic and electro-optical technologies, materials science, advanced RF technology, and quantum information science to develop innovative system applications and components

Leadership

Robert G. Atkins
Division Head

Mark A. Gouker
Asst. Division Head

Livia M. Racz
Asst. Division Head



Laboratory researchers are combining germanium detectors with digital focal-plane array technology to develop low-noise, high-speed shortwave infrared sensors. The germanium detectors on the wafer shown above were fabricated in the Microelectronics Laboratory.

Principal 2024 Accomplishments

- To support the fabrication of advanced smart fabrics, Laboratory engineers developed a textile circuit board by laser cutting a conductive layer on a fabric core to produce pads, traces, and interconnects. The textile circuit board will provide a scalable technology platform for applications that require embedded electronics across large areas or curved surfaces.

- A six-antenna electromagnetic-wave vector sensor developed by the Laboratory was deployed on the island of Palau. The sensor collects high-frequency signals of opportunity from coastal oceanographic radars to advance understanding of the ionosphere. Designed to provide a long-term unattended data collection capability, the sensor has captured a nearly continuous stream of data over the past year.

- Record yield was achieved on large-format microwave kinetic inductance detectors. The detectors have applications in extremely photon-starved observations, such as direct exoplanet imaging. The Laboratory leveraged decades of investment in the Microelectronics Laboratory's superconductor electronics process and collaborated with University of California, Santa Barbara.

- The Laboratory developed a photon-counting detector specifically applicable to brain functional imaging via a technique called diffuse correlation spectroscopy. The detector has been demonstrated in model systems and will be tested on human subjects in collaboration with the Athinoula A. Martinos Center for Biomedical Imaging at Massachusetts General Hospital.

- The Laboratory successfully tested the Wideband Selective Propagation Radar System (WiSPR) at the U.S. Army Aberdeen Proving Ground. A significant advantage of WiSPR is its capability to counter adversary signals intelligence.

- Laboratory researchers tested a multiband reflectarray antenna as they work toward demonstration of a 0.6 m × 0.9 m electronically scanning antenna that provides independent beams at 24 GHz, 31 GHz, and 50–58 GHz. The antenna aims to improve space-based microwave radiometry systems, which are critical to weather forecasting and climate monitoring.

Future Outlook

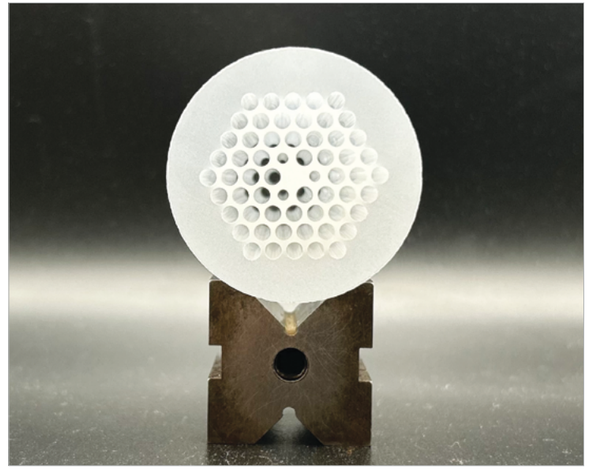
The Laboratory will continue engaging in Microelectronics Commons projects funded under the federal CHIPS and Science Act. Many of these projects will utilize the Laboratory's microelectronics fabrication facilities and bring together broad teams involving academia and industry.

The Laboratory expanded its program to supply superconducting qubit foundry capabilities to U.S. universities. Under this program, a growing number of collaborative partners will receive qubit circuits fabricated in the Microelectronics Laboratory.

The materials-by-design project will significantly accelerate the development of application-specific materials. Progress will continue in two key areas: artificial intelligence to help identify candidate materials, and highly parallel methods to create and characterize selected materials.

Subtractive Manufacturing of Photonic-Crystal Fibers

Photonic-crystal fibers are optical fibers that guide light through an arrangement of small, closely spaced air holes running the length of the fiber. Such fibers are critical components in specialized laser systems, such as those for generating supercontinuum light. Laboratory researchers developed a process for leveraging subtractive manufacturing to create photonic-crystal-fiber preforms, including the preform pictured here, which can then be drawn into fiber. The Laboratory's process uses a five-axis mill machine to drill holes in glass, in contrast to traditional stack-and-draw techniques in which glass rods are carefully arranged. This new process obviates the need for radial symmetry and maximizes reconfigurability of fiber designs, unlocking new application spaces.



Homeland Protection

Innovating technology and architectures to help prevent attacks on the U.S. homeland; to reduce the vulnerability of the nation to terrorism; and to improve the security and resiliency of critical infrastructure, including energy systems, against natural and human-made threats

Leadership

Jennifer A. Watson
Division Head

James K. Kuchar
Asst. Division Head

Jonathan D. Pitts
Asst. Division Head

Chris A.D. Roeser
Asst. Division Head

Lincoln Laboratory developed a test bed at Ramstein Air Base in Germany for evaluating air defense sensors, software, and decision support tools. This test bed was downsized for an exercise in Florida, where team members, above, deployed sensors identical to those tested in Germany.

Principal 2024 Accomplishments

- At the Astral Knight air defense exercise in Poland, the Laboratory fielded a redeployable version of its prototype European air defense system and a decision support architecture on a U.S. Air Force test network to support operators in a simulated scenario.
- The Laboratory deployed two new target-tracking capabilities to the Air Force Cloud One environment: a near-real-time analytics test bed for assessing the performance of air-domain track fusion, and a prototype artificial intelligence (AI) tool that detects anomalous air tracks.
- The Laboratory prototyped and tested a passive radar system for mitigating interference from wind turbine systems.
- The Laboratory designed and began fabrication of a two-panel, digital-at-every-element phased array radar prototype to demonstrate next-generation radar technology funded by NOAA's National Severe Storms Laboratory.
- For the U.S. Coast Guard, the Laboratory continued to advance maritime domain information architectures through model development and workflow optimizations.
- New tools were developed for countering foreign influence operations, including technologies for surveying, simulating, and predicting hostile influence networks online.
- For U.S. Customs and Border Protection, the Laboratory demonstrated a software system to integrate disparate sensors over a wide area. The technology can locate activity of interest and predict the trajectory of potential threat movement.
- The Laboratory continued to rapidly prototype solutions for the U.S. Special Operations Command to enhance situational awareness for forward-deployed joint forces.
- An energy-resilience analysis tool is enabling researchers to assess the impact of power outages and emerging technologies, such as geothermal or micronuclear reactors, on DoD energy systems.
- At DoD installations, the Laboratory conducted control-system resilience exercises in which cyberattacks were simulated to demonstrate mission impact to critical infrastructure.

Future Outlook

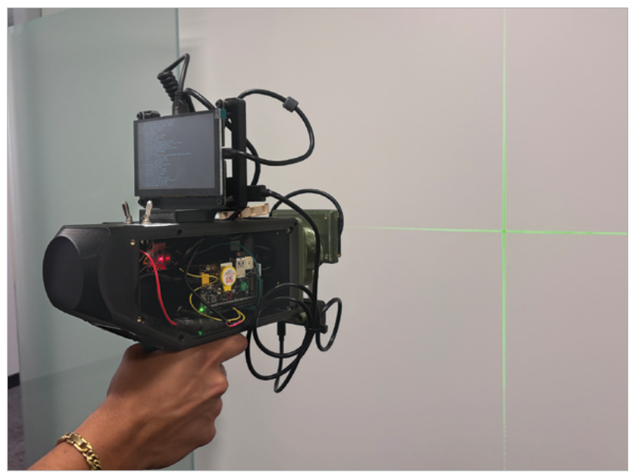
The Laboratory will continue to assess emerging threats to the homeland and develop both architectures and prototype systems to provide enhanced air defense and critical infrastructure protection, leveraging technology advancements in both sensor hardware and algorithms.

The Laboratory will be a pathfinder for homeland security uses of emerging AI technologies to provide timely and actionable information in application areas, including investigative tool kits, critical infrastructure and soft-target protection, foreign influence operations, and border and maritime domain awareness.

The Laboratory will continue to innovate new approaches to critical infrastructure resilience to counter both adversary and climate-induced threats, with a particular focus on energy, water, and communication systems.

Through-the-Wall Radar System

The Laboratory has expanded its portfolio of radar prototypes capable of detecting activity behind walls. An initial through-the-wall prototype system integrated radar on an uncrewed ground vehicle. Researchers have since evolved the radar prototype to compensate for platform motion, enabling handheld versions or deployments on uncrewed aerial vehicles. Pictured here is a prototype handheld radar, which leverages a combination of low-cost commercial-off-the-shelf and 3D-printed components and advanced signal processing algorithms. Through-the-wall radar systems can provide new search-and-rescue capabilities to first responders.



Biotechnology and Human Systems

Advancing technologies and systems for improved chemical and biological defense, human health and performance, responses to the impacts of extreme weather, and resilience to both natural and human-made disasters

Leadership

Edward C. Wack
Division Head

Jeffrey S. Palmer
Asst. Division Head

Christina M. Rudzinski
Asst. Division Head

Lincoln Laboratory is developing biosynthetic methods to manufacture cleaner, safer, and less-expensive chemicals and materials that are critical to national security but often sourced internationally. Above, Jamie Stankiewiz, front, and Emily Kurdzo prepare a fermentation test.

Principal 2024 Accomplishments

- Lincoln Laboratory delivered a machine learning software tool to the Federal Emergency Management Agency. The tool rapidly and automatically finds and labels thousands of Civil Air Patrol images collected after a disaster, saving countless hours of manual labeling and accelerating disaster response times.
- A multidisciplinary Laboratory research team developed a multilingual digital evidence analysis system to assist federal law enforcement agency special agents and analysts in their efforts to counter the production and distribution of illicit fentanyl.
- The Laboratory performed a roadmap study that helped the Department of Homeland Security Countering Weapons of Mass Destruction Office identify approaches for detecting and characterizing biological agents, without prior knowledge of the threat.
- A low-cost, hardened chemical vapor sensor that will remotely detect and report the presence of chemical threats or other toxic substances was delivered for performance evaluation in a military fielding exercise representative of hazardous operational environments.
- To ensure military operational readiness, the Laboratory led the development of an integrated biosurveillance architecture that enables early detection of health threats and weapons of mass destruction.
- At the 2024 Beholder's Gaze event, the Laboratory modeled and simulated physiological measurements of a joint military force, which were then combined with live data streams from wearable devices and fed into predictive algorithms. The resulting predictions can provide early warning of illness and support decision-making.
- The Laboratory developed a quantitative dynamics model to help optimize and guide the implementation of the National Disaster Medical System in the event of a complex humanitarian emergency or large-scale combat operation.
- To improve U.S. Navy service member readiness and endurance, Laboratory staff upgraded a data movement and analytics system that monitors sailor fatigue in real time to assist commanders with underway decision-making.

Future Outlook

Improving humanitarian assistance, global health, and disaster response activities, and reducing the security impacts of extreme weather events, will motivate work on advanced architectures, sensors, and analytics.

The Laboratory will develop advanced technologies and system architectures for chemical and biological threats, including pandemics, to protect deployed forces and civilians.

Improving soldier health and performance will require advances in brain-related technologies, physiological sensors, and engineered and synthetic biology.

Artificial intelligence will be leveraged to interpret vast amounts of biological and health data, assist in decision-making, and provide insights for new discoveries.

Synthetic Tissue Model For Testing Medical Technologies

Lincoln Laboratory and Massachusetts General Hospital are collaborating to prototype and test medical technologies to care for wounded service members in austere, prehospital environments. To test these technologies at early stages of development, the team developed a 3D-printed synthetic tissue model containing femoral vessels and portions of the pelvis and femur. The model was built using computed tomography to capture anatomical differences found within a diverse patient population, enabling more accurate testing and validation. At right, U.S. Air Force Lt Col Jennifer Wolf, MD, a Lincoln Laboratory Military Fellow, uses the tissue model to demonstrate a field-portable, AI-enhanced ultrasound system.

Air Traffic Control

Developing advanced technologies and decision support architectures for surveillance, integrated weather sensing and processing, collaborative traffic management, information security, and optimization to support the nation's air transportation and logistics systems

Leadership

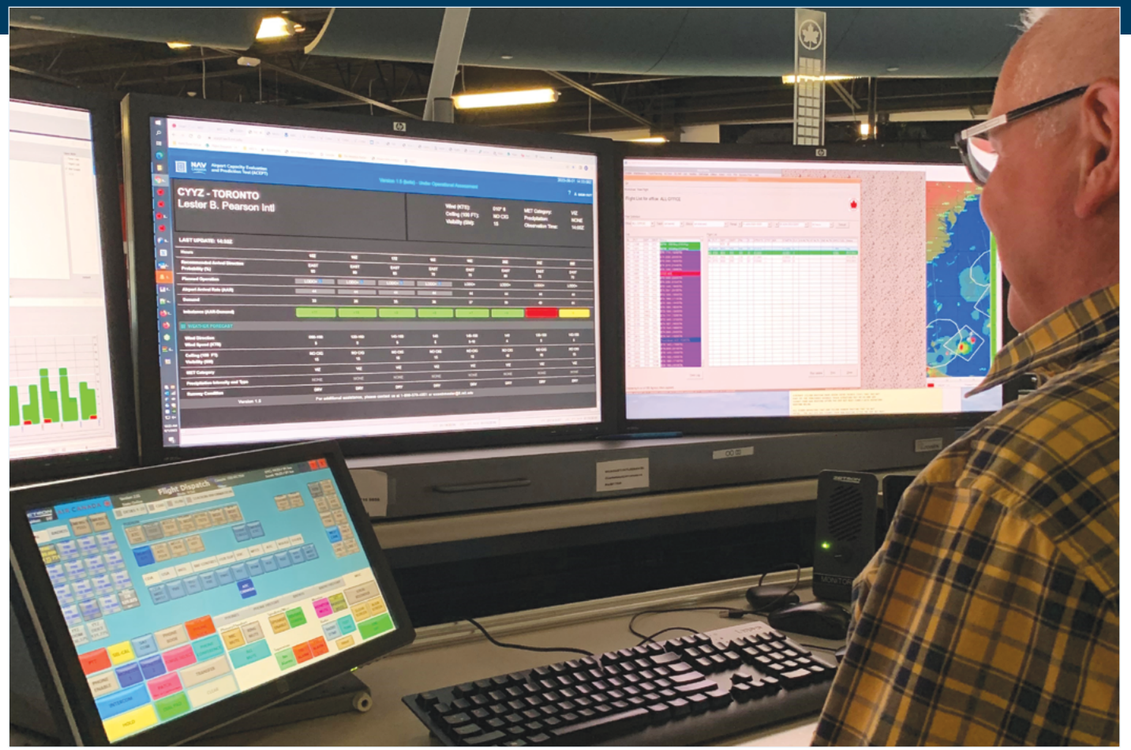
Jennifer A. Watson
Division Head

James K. Kuchar
Asst. Division Head

Jonathan D. Pitts
Asst. Division Head

Chris A.D. Roeser
Asst. Division Head

James M. Flavin
Principal Staff



Lincoln Laboratory collaborated with NAV CANADA to develop integrated technologies for predicting the impact of weather on aviation. Here, an airline dispatcher uses the Laboratory's Airport Capacity Evaluation and Prediction Tool to assess capacity and demand at Toronto Pearson Airport.

Principal 2024 Accomplishments

- The Laboratory continued finalizing development of the Airborne Collision Avoidance System X (ACAS X) for rotorcraft and advanced air mobility vehicles. Laboratory researchers also continued working with operators and industry to implement and evaluate the performance of ACAS X variants for large and small uncrewed aircraft.
- The Laboratory adapted safety logic built for the nationally deployed Runway Status Lights systems to accommodate Automatic Dependent Surveillance – Broadcast and a novel surface movement radar.
- The Laboratory collaborated with the Federal Aviation Administration (FAA) and NASA to address the airspace integration demand for new, increasingly autonomous vehicles and operations, such as small uncrewed aircraft and urban air mobility.
- The Laboratory supported technology development, analysis, and prototyping for FAA air traffic management, weather sensing, and processing architectures including the NextGen Weather Systems.
- The Laboratory is supporting the FAA Weather Cameras program to improve aviation safety through automated weather observations at remote locations. Image processing techniques are being used to translate weather camera imagery into visibility estimates to support pilot decision-making.
- To address the DoD's weather tracking and forecasting needs, the Laboratory continued to develop synthetic weather radar, contrail forecasting capabilities, and numerical weather model–blending algorithms.
- The Laboratory facilitated the use of zero-trust cybersecurity architectures in air traffic control systems. The Laboratory developed technologies that leverage artificial intelligence (AI) and machine learning to assess, detect, and mitigate cybersecurity threats in the commercial aviation ecosystem.
- Laboratory staff continued to support the U.S. Transportation Command in research areas including optimized mission planning, global bulk fuel management, agile basing, mass-casualty decision support, and force health protection.

Future Outlook

The Laboratory will continue R&D in advanced aviation system concepts, including trajectory-based operations, collision avoidance, new airspace entrants (e.g., space transportation, high-altitude operations, and urban air mobility), and environmental impact reduction. Cybersecurity efforts will address potential vulnerabilities in aviation systems, and the Laboratory will continue to develop technical performance standards, safety evaluation methods, and threat-avoidance algorithms for aviation.

The Laboratory will innovate sensing technologies, forecasting systems, and algorithms for managing weather-impacted airspace capacity. Meteorological surveillance of severe storms will improve as engineers develop next-generation digital phased array radar systems. Advanced techniques will be used to allocate resources more efficiently for civilian and DoD transportation.

Airport-Traffic-Pattern Safety System

The Laboratory partnered with Thrust AI, a company specializing in AI-enabled flight management software, through a Small Business Technology Transfer project to enhance airport-traffic-pattern safety at U.S. Air Force undergraduate pilot training bases. The system developed through this project uses aircraft surveillance information and a low-cost electro-optical camera to automatically monitor the final approach segment of an aircraft's landing pattern. Here, the prototype system tracks an Air Force T-6 training aircraft to verify that the aircraft's landing gear is properly configured. Laboratory and Thrust AI collaborators will further develop the system to improve the effectiveness of pilot training by providing users with conflict alerts.

Engineering

Employing expertise in a broad range of interdisciplinary engineering fields to design, build, integrate, test, and field advanced prototype systems and enabling technologies

Leadership

Ted David
Division Head

Keith B. Doyle
Asst. Division Head

Kristin N. Lorenze
Asst. Division Head

The Laboratory developed single- and multi-agent perception, planning, and control algorithms for the U.S. Army's ground robotics portfolio. Above, Clayton Dembski, left, and Dan Stoianovici prepare to demonstrate an autonomous vehicle programmed with these algorithms.

Principal 2024 Accomplishments

- The Laboratory continued collaborating with the U.S. Space Force and a partner organization in Japan to integrate and environmentally test two space domain awareness payloads on Japanese satellites.
- Laboratory engineers built a compact, wide-field-of-view, pressure-balanced camera for use in high-pressure deep-sea environments and tested the camera under water.
- NASA awarded the Laboratory funding to mature structural materials for the Habitable Worlds Observatory, a telescope for finding exoplanets. The materials will enable telescope components to fold before launch and unfold once in space.
- A Laboratory team developed a novel airborne interferometric methane sensor that can survey large areas to detect natural gas leaks. The sensor was successfully demonstrated during ground testing.
- Laboratory staff built and tested a prestressed optical mount that compresses hypersonic vehicle windows to protect them in extreme thermal conditions.
- Researchers at the Laboratory developed and tested an uncrewed aerial vehicle with deployable wings. They used novel fabrication methods to create multifunctional parts key to the wings' highly integrated design.
- To accelerate research and development in autonomous ground vehicles, the Laboratory developed and deployed a cloud-based architecture and data warehouse prototype for the U.S. Army's Ground Vehicle Systems Center.
- Researchers developed advanced artificial intelligence and machine learning techniques to complement traditional modeling and simulation techniques for engineering applications ranging from hypersonics to microfluidics. The Laboratory-developed software tools perform multidisciplinary design and optimization faster than current techniques.
- To its fabrication shops, the Laboratory added new capabilities for improving the precision, accuracy, range, efficiency, and throughput of fabrication processes that will enable advanced prototype development.

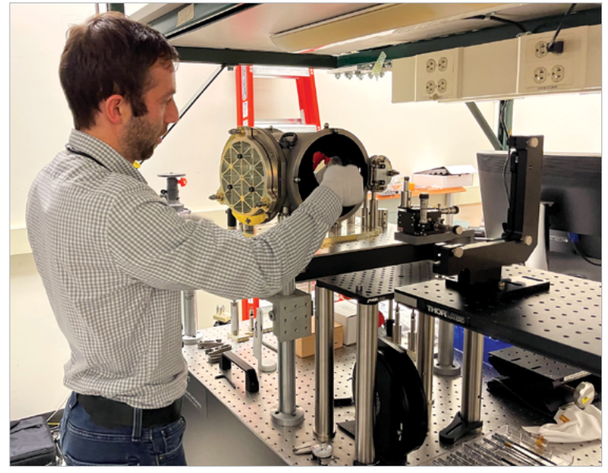
Future Outlook

Working with architectural firms, the Engineering Division will finalize the design of the new Engineering Prototyping Facility, which will enable the Laboratory to develop increasingly complex prototypes for future national security needs. Construction is expected to start in 2027, and the building is scheduled to open in 2029.

The Laboratory's increasing use of digital engineering enablers—such as model-based practices, integrated modeling and simulation, connected planning and execution, digital-twin technology, and artificial intelligence—will accelerate the development of innovative prototypes. The Laboratory will also expand its participation in relevant DoD strategic initiatives to develop and deliver capabilities that more rapidly address emerging threats and technology gaps.

Next-Generation Freeform Telescope

A Laboratory team developed a wide-field-of-view, reflective, afocal telescope to enable high-precision applications. They built the compact, lightweight, and low-power telescope by using Laboratory-developed efficient, freeform ray-tracing software to design multiple mirrors with advanced surfaces. Here, Chris Roll adjusts one of the mirror mounts to bring the telescope into alignment. The team rapidly fabricated the prototype telescope via diamond turning and developed novel actuators for optical mounting and machine learning algorithms for alignment that dramatically reduced alignment time. Researchers have conducted additional optomechanical design and analyses to ruggedize the telescope for future use.



TECHNOLOGY INVESTMENTS 37

A quantum diamond at the center of a magnetic microscope fluoresces red light when excited by a green laser. This fluorescence can be used to create images of magnetic fields, useful for inspecting microelectronics among other applications.

Technology Investments

TECHNOLOGY OFFICE

The Technology Office manages Lincoln Laboratory's strategic technology investments and helps to establish and grow technical relationships outside of the Laboratory

LEADERSHIP

(Left to right)

Q. Chelsea Curran
Associate Technology Officer

Sandeep S. Pisharody
Associate Technology Officer

Heidi C. Perry
Chief Technology Officer

Shireen M. Warnock
Associate Technology Officer

The office achieves these objectives through several activities:

- Overseeing investments in both mission-critical technology and potentially impactful emerging technology
- Interacting regularly with the Office of the Under Secretary of Defense for Research and Engineering and other government agencies to maintain awareness of emerging national security problems and applicable technologies
- Fostering collaborations with MIT campus and other university researchers
- Aiding in the transfer of next-generation technology to the Laboratory's mission areas
- Enhancing inventiveness at the Laboratory through various investments and programs that promote a culture of innovative thinking and creative problem solving

TECHNOLOGY OFFICE INVESTMENT AREAS

INVESTMENTS IN MISSION-CRITICAL TECHNOLOGY

Enabling development of technologies that address long-term challenges and emerging issues within the Laboratory's core mission areas

Information, Computation, and Data Exploitation

Research in the information, computation, and data exploitation domain addresses challenges in the application of emerging AI and big data technology for national security needs. Themes of current research are data and artificial intelligence (AI) algorithms, computing foundations, human–machine teaming, and AI systems engineering. Projects in 2024 enabled

- An end-to-end deep neural network to control a fighter jet. A Laboratory team applied mission-ready reinforcement-learning technology to support the development of this AI pilot, which executed live maneuvers against a human pilot at Edwards Air Force Base.
- Efficient and adaptable robust-learning algorithms that leverage radar domain knowledge for enhanced discrimination to improve missile defense systems.
- Enhanced AI systems engineering and reliability technology to address challenges of brittleness and vulnerability in AI systems. The technology was transitioned to the Joint AI Test Infrastructure Capability within the Chief Digital and Artificial Intelligence Office.
- Interdisciplinary research in developing critical human–machine teaming technologies to demonstrate mission-relevant capabilities for national security.

Information, Computation, and Data Exploitation

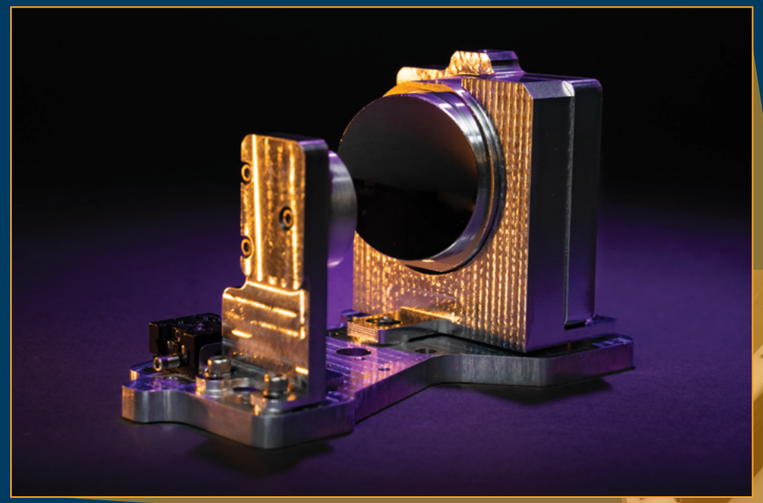
AI-Accelerated Pipelines for Radar-Modeling Tasks

The development of AI-accelerated pipelines for radar-modeling tasks will advance defense capabilities that counter highly evolving and diversifying threats. In 2024, a Laboratory team demonstrated the effectiveness of a custom physics-informed deep learning model in generating radar signatures. Additional design steps (not native to off-the-shelf neural networks) allow the model to predict how a radar signature would change with a sensor's observation angle, without the model requiring extensive training data. These extra steps also provide performance guarantees for model behavior, a key requirement in DoD applications needing high-confidence observations.

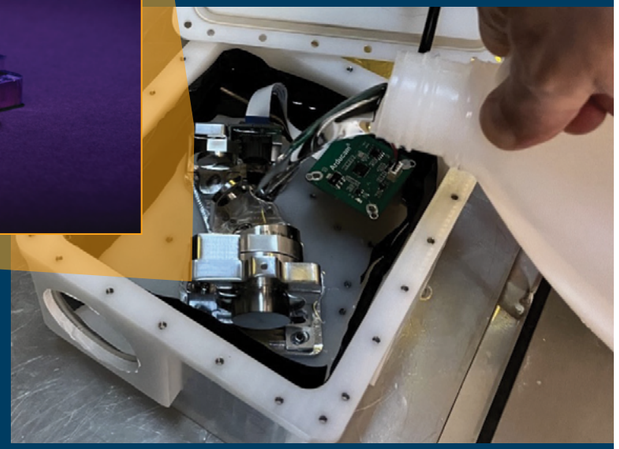
>> *Investments in Mission-Critical Technology, cont.*

TECHNOLOGY HIGHLIGHT: Optical Systems Technology

Freeform Optics and the Fisheye Camera



The mirror lenses of the underwater optical system, shown left, were designed and fabricated via diamond turning at the Laboratory. The two-mirror freeform optical design provides a wide field of view and large aperture. Below, the box enclosure housing the camera is filled with oil, which will enable the camera to withstand high pressures.



This oil-filled enclosure allows the system to withstand extreme underwater pressures.

Efficient, high-quality underwater imaging could bring light to the 80% of ocean that remains unexplored. Current deep-sea underwater cameras use optical lenses placed behind thick optical viewports in heavy and expensive pressure vessels, limiting their practical use. Lincoln Laboratory is developing a compact, low-cost camera that could operate at significant depth without a pressure vessel.

The camera's design, inspired by the fluid-filled lens of a fish's eye, makes use of reflective optics, or mirrors. Traditional cameras that use glass lenses lose their focusing power when submerged in water, owing to the low refractive-index difference between glass and water. In contrast, reflective optics can retain their focus regardless of the medium they are submerged in, because their focusing power comes from their curvature and not their refractive index. The Laboratory-designed camera uses two freeform mirrors (mirrors having a nonsymmetrical surface) that provide a wide-angle field of view. The camera is fully submerged in silicon oil, which is a nearly incompressible fluid, within a box enclosure.

The camera could open up new and previously cost-prohibitive exploration missions and security applications—such as monitoring ports, fisheries, or energy-industry activities and inspecting undersea cables and pipelines. With its small size and weight, the camera can be attached to an undersea vehicle; it can also be fixed at one location. An ultraviolet light installed on the camera's window mitigates biological growth.

Naturally achromatic and insensitive to temperature and pressure, the camera could also find use in a multitude of applications beyond the deep sea: from rugged terrestrial systems, to airborne systems, or small satellites.

Optical Systems Technology

Research into optical systems technology enables future mission capabilities in intelligence, surveillance, and reconnaissance (ISR) and communications. The goal of this research is to fill critical technology gaps in emerging DoD threat areas. Projects emphasize research in lidar, high-energy lasers, imaging systems, optical communications, and novel optical components. In 2024, projects achieved notable progress, including

- Detecting human motion through foliage in an outdoor field test utilizing a novel coherent Doppler lidar system. Algorithms developed to analyze the lidar data discriminated between humans and background clutter such as wind-blown leaves. The demonstration is an important step in identifying moving targets on the ground through dense foliage.
- Achieving multinode time transfer over optical-fiber-linked modems with velocity-error emulation and correction for satellite use scenarios. Preliminary experiments using low-cost, off-the-shelf hardware demonstrated precision time transfer of less than 10 nanoseconds, a performance on par with typical GPS time-transfer accuracy.
- Investing in new mission-enabling concepts to replace traditional adaptive-optics systems at ground stations for free-space laser communications.
- Demonstrating a device that can switch between being thermally absorptive and reflective via an electrowetting process. The device could be used in thin, tunable radiators for small satellites.

Cybersecurity

The DoD requires the ability to operate in and through cyberspace to protect the American people and advance the defense priorities of the United States. As the DoD increases its multidomain integration and as threat actors increase their cyber operations in scope and sophistication, the national need to operate in a contested cyber environment requires both secure and resilient systems-of-systems and survivable cyber capabilities. In 2024, the Laboratory continued fundamental research in cybersecurity phenomenology, resilient systems, and cyber-capability enablers, with emerging emphasis on AI technologies applied to the problem space. In 2024, this portfolio developed

- Automation techniques that rapidly produce emulation environments for binary-code segments, accelerating reverse engineering and vulnerability discovery for embedded systems code.
- Survivability technologies to enhance the ability of offensive cyber operations to minimize mission risk with techniques such as environmental keying and secure computation for deconfliction.
- Proof-of-concept kernel segmentation technology that was incorporated into a resilient hypervisor to improve the security of cloud systems.
- A foundational model for RF classification tasks and specific emitter identification to improve the security of systems relying on RF communications.

Cybersecurity

Heimdall Program

The Heimdall program is developing cutting-edge AI algorithms that can be used to help contextualize a warfighter's RF environment. One application is specific emitter identification, where AI models learn to leverage unique physical imperfections in device manufacturing processes to identify specific devices transmitting in the RF spectrum. This capability provides a contextual awareness that enhances the warfighter's ability to gather intelligence, conduct surveillance, or perform reconnaissance to discriminate particular targets of interest. In this 3D illustration, a soldier uses an AI-enabled device to scan the environment for RF sources, shown in blue, and identify a particular source of interest, shown in red.

>> Investments in Mission-Critical Technology, cont.

Integrated Systems

Projects in the integrated systems category bring together scientists and engineers to conduct applied research that accelerates the integration of advanced technologies into systems addressing national security needs. The goal is to demonstrate DoD-relevant system concepts that use novel architectures, component technologies, and analytic methods. Projects include

- An optical-imaging payload for satellites in a low-Earth-orbit constellation that could enable global surveillance at rapid update rates. The team met fabrication milestones for the build of a first-of-its-kind focal plane array with on-chip image processing; matured and tested new algorithms for real-time image compensation; and constructed a compact, wide-area scanning optical test bed for system demonstrations and concept refinement.
- An architecture to enable autonomous volume sensing of the world's oceans for accurate forecasting. The team studied the feasibility of a multispectral imaging satellite for tracking biomass, ocean currents, and ocean chemistry, and airborne and spaceborne lidar systems for measuring the temperature and salinity profile of the upper water column.
- An investigation of the engineering feasibility of a broadband stimulated-Raman-scattering system that could provide rapid, high-confidence chemical and biological identification in field-deployed environments. The team focused on options for a broadband fiber-laser source required for miniaturizing the instrument and improving robustness over free-space laser sources.

Emma Chadwick operates a prototype optical system consisting of a novel scanner paired with an advanced camera capable of digital processing at the pixel level. This combination potentially enables rapid wide-area scanning in a compact form factor that could fit on small satellites for global surveillance applications. Current laboratory testing is focused on characterizing system performance and developing key image-processing algorithms.

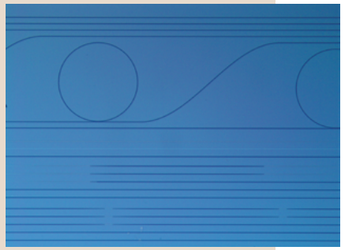
Radio-Frequency Systems

Research and development in RF systems is exploring innovative technologies and concepts in radar, signals intelligence, communications, and electronic warfare. Emerging national security challenges include a rapidly expanding threat spectrum, the integration of sensors on platforms with constrained payloads, operations in strong clutter and interference environments, detection and tracking of difficult targets, and robustness against sophisticated electronic countermeasures. To address these mission requirements, current research projects focus on innovative antenna-array topologies and construction, hybrid photonic-electronic systems, and advanced algorithms. Project teams are developing

- Ultrastable photonic-based local oscillators. Initial results indicated an order-of-magnitude improvement in phase noise over current state-of-the-art tactical oscillators.
- Machine learning algorithms that allow blind adaptive beamforming from antenna arrays on short-duration, low-signal-to-noise-ratio signals, without knowledge of training sequences.
- A photonics-based tunable finite-impulse-response filter with multiple applications, including spectrum analysis.

RF Systems

Photonic-Enabled Ultra-Low Phase Noise RF Synthesizer Project



Electronic oscillators lie at the heart of virtually all microelectronic systems, generating the signals used in digital electronics and the precise frequencies that enable radar and RF communications. An ideal oscillator provides a tone at a singular frequency, but real-world sources have component imperfections and environmental-coupling effects that degrade performance. The Photonic-Enabled Ultra-Low Phase Noise RF Synthesizer project is developing high-performance, photonics-based microwave sources in a compact volume typical of far noisier chip-scale solutions. A recently fabricated photonic integrated circuit is shown, with multiple waveguides and layers designed to enable dense routing and high-quality optical resonators.

INVESTMENTS IN EMERGING TECHNOLOGY

Promoting research into technologies of growing importance to national security and the development of engineering solutions for projects in Lincoln Laboratory's relevant mission areas

Autonomous Systems

Autonomous systems are a critical technology development area for the DoD and other national security organizations. While platform and sensor capabilities have improved, technology gaps remain with respect to individual and collaborative robots making complex decisions, and robots seamlessly integrating with human teammates. To address these gaps, the Laboratory conducts applied research in three areas: intelligent perception and decision-making algorithms; multiagent expeditionary systems, including human–machine teams, with a focus on trust and explainability; and rigorous approaches to verification and validation of closed-loop systems. In 2024, researchers working in autonomy

- Demonstrated autonomous situational awareness in challenging, unstructured outdoor and underwater environments. Historically, perception technologies have not been effective outdoors because of a lack of interpretable observations. Researchers addressed these limits by constructing hierarchical topologies of outdoor beachhead scenes, from which they assembled meaningful, navigable scene graphs.
- Performed initial tests in collaborative navigation between an autonomous underwater vehicle (AUV) and a human diver. The team tested algorithms that use sonar returns to classify objects and assessed designs that improve AUV-assisted diver-state estimation in open-water tests. The eventual goal is bidirectional diver-and-AUV underwater localization, tracking, and decision-making.
- Advanced the focus on correct-by-construction, explainable mixed-integer reinforcement learning to policy selection, with applications in autonomous adversarial game playing and robot training by demonstration. Teams and collaborators are participating in joint Army, Navy, and DoD international competitions that pit teams and tactics against each other to demonstrate relative advantages in disparate DoD-relevant missions.

Autonomous Systems

Autonomy al Fresco

Autonomy al Fresco is a collaborative project with MIT Professors Sertac Karaman and Luca Carlone to develop outdoor 3D-scene-graph mapping technology useful for search-and-rescue missions. The technology aims to enable autonomous robots, such as this Boston Dynamics robotic dog being operated here by Robert Frei, left, and Matthew Trang, to exhibit high-level reasoning. Previous mapping technology, which has largely focused on indoor environments, has omitted conceptual information that could be used for more advanced reasoning or human interpretation.

>> *Investments in Emerging Technology, cont.*

Human Resilience Technologies

The Human Resilience Technologies portfolio emphasizes investments in system prototypes and architectures in sensors, analytics, and decision support systems that support community resilience and disaster-response capabilities. Research thrusts span hazard forecasting and early-warning systems, remote assessment and situational awareness technologies, decision-making tools and analytics for sparse-data environments, disruption-resilient communication and critical-service technologies, new methods in disease surveillance and secondary-effects modeling, and technologies to combat human exploitation. Activities from 2024 include

- Applying predictive-analytics techniques to domestic wide-area search-and-rescue squad data. When combined with geospatial analytical methods, these techniques can automatically generate accurately sized squad search segments, enabling first responders to quickly determine the number of resources to deploy and the locations to which these resources should be assigned.
- Assessing and piloting the application of large language models for special use cases in disaster relief.
- Investigating the phenomenology of ad hoc RF waveguide generation for the detection of survivors in collapsed building debris.
- Studying approaches for using swarms of uncrewed aerial systems to support post-disaster search-and-rescue missions.

Laboratory researchers place a broadband antenna into a rubble pile (used for research purposes) to detect RF signals generated using metallic structures within the rubble pile. The antenna amplifies RF signals that would otherwise be too weak to pick up. Search-and-rescue teams could then use digital signal processing to look for changes in the RF signature indicating the presence of an individual within a collapsed structure.

Quantum System Sciences

Quantum information science is a fusion of quantum mechanics and information theory—two foundational fields underpinning modern technology—that could yield transformative new types of sensors, computers, and interconnects with potential for significant economic and national security implications. The Technology Office investment in quantum system sciences is advancing and democratizing access to quantum bit (qubit) platforms at the Laboratory and in the United States, accelerating impact with quantum devices born from rigorous system-driven design, and enabling next-generation advances through quantum theory. In 2024, key achievements included demonstrations of

- A superconducting qubit platform extensible to quantum computing. The platform achieved a level of quantum coherence in a 3D-integrated system that had previously only been shown in less-scalable planar designs.
- A scalable quantum memory module to move delicate quantum states between systems. Based on silicon-vacancy centers in diamond, each module uses eight individually addressable diamond waveguide memories. This technology received successive R&D 100 Awards the last two years.
- An ion optical clock in a manufacturable, integrated photonic platform with stability exceeding that of existing maser technology. This clock uses the precise transitions between energy levels within individual ions to measure time and can scale to achieve a six-fold improvement in performance over current GPS clocks.

TECHNOLOGY HIGHLIGHT: Quantum System Sciences

Solid-State Magnetic Imaging

Microelectronics are essential for national security and economic prosperity. With the United States increasingly reliant on foreign production, the dual needs of expanding U.S.-based manufacturing and ensuring supply chain security are critical. These needs rely on effective microelectronics diagnostic tools to ensure robustness in fabrication processes and to safeguard resultant systems. Existing tools can be slow, invasive, exceedingly delicate, or unable to pinpoint the locations of anomalies in integrated circuits. Furthermore, as microelectronics technology advances in sophistication, many traditional tools lose effectiveness altogether. Widefield magnetic microscopy using quantum defects in diamond (known as nitrogen-vacancy, or NV, centers) is an emerging technology area that allows for noninvasive, nondestructive, and rapid spatial localization of electrical currents even in increasingly complex architectures. This technology overcomes limitations of conventional techniques, enabling a new generation of advanced diagnostic tools.

The Quantum Solid-State Magnetic Imager of Currents (QOSMIC) program is developing and employing a high-performance diamond magnetic microscope with a unique combination of wide field of view, high sensitivity, and high bandwidth to detect spatiotemporally varying currents for microelectronics diagnostics. By optically probing the magnetically sensitive NV spin defects in a custom-fabricated diamond crystal and imaging the diamond fluorescence on a camera, the system can create images of magnetic fields. When a device is placed in proximity to the diamond, the magnetic fields generated by currents in the device can be mapped with micron-scale spatial and millisecond-scale temporal resolutions, at frequencies from direct current to 100 MHz, and near 3 GHz.

The microscope has been validated on a series of test devices, and it is now being applied to troubleshoot integrated circuits that are of value to the failure analysis and trusted and assured microelectronics communities. In parallel, enhanced magnetic image interpretation techniques are in development to precisely confine the depth of detected anomalies, demonstrating the technique's applicability to 3D heterogeneously integrated circuits and other increasingly complex architectures. To expand the performance of the technology even further, time-sampling techniques are being applied to increase the temporal resolution to microseconds or even tens of nanoseconds.

With improved magnetic-image interpretation techniques and new high-performance instrumentation capabilities, this effort aims to localize electronics anomalies that are difficult or impossible to detect with conventional methods. If successful, this instrument will become an invaluable standard tool for electronics interrogation to ensure U.S. national and economic security, with broad adoption by both government and commercial end users.

The quantum diamond at the sensor head of the magnetic microscope fluoresces red light when excited by a green laser. The fluorescence comes from quantum defects called nitrogen-vacancy (NV) centers. The NV centers detect nearby magnetic fields, such as from currents in electronics, and encode those fields in the fluorescence intensity. By imaging the NV fluorescence on a camera, high-resolution images and high-speed movies of spatially varying magnetic fields are produced.

>> *Investments in Emerging Technology, cont.*

Advanced Devices

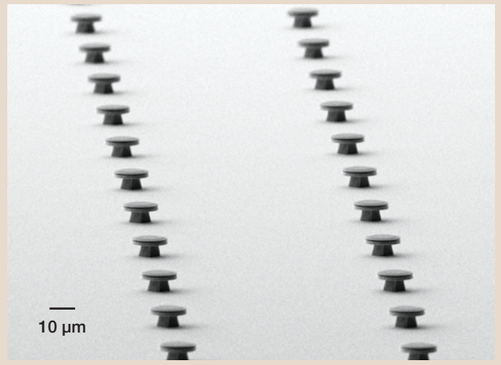
Work in advanced devices focuses on developing components and capabilities to enable new system-level solutions to national security problems. Advanced devices span a wide range of fundamental technologies, including RF technology, lasers, advanced computing, imagers, detectors, and microsystems. Projects in 2024 demonstrated

- A three-layer (nine-core) artificial neural network with local memory. This work is part of a larger need to develop energy-efficient superconducting circuits for AI– and machine learning–based microelectronics to address the increasing demand for neural networks.
- A 90 nm self-aligned replacement-metal-gate ferroelectric transistor to enable high-throughput computation with low power. Energy-efficient ferroelectric devices can be used as building blocks for in-memory computing hardware-based AI accelerators, potentially reducing power and memory bandwidth demands by orders of magnitude.
- A high-yield, large-format array of microwave kinetic inductance detectors for enabling applications in astronomy, space domain awareness, and maritime imaging. The array detects without false counts the arrival time and wavelength of every photon reaching an imager.

Advanced Devices

Geiger-Mode Avalanche Photodiodes

Geiger-mode avalanche photodiodes (APDs) are critical to lidar and optical communication systems, enabling single-photon detection with subnanosecond timing. Such APDs are used widely in airborne platforms, but their operation in space is limited by radiation that degrades their performance. To overcome this limitation, the Laboratory is developing radiation-hardened APDs, the first generation of which are shown in the image below taken by a scanning electron microscope. If successful, this technology will extend the operation of APDs to more extreme environments, enabling a wide range of NASA and DoD applications.



Advanced Materials and Processes

This research area seeks to invent materials and methods that dramatically accelerate the development and transition of materials, and to leverage these methods to develop discriminating sensing, computing, imaging, and manufacturing capabilities for the nation. Key efforts harness AI, rapid prototyping, and nanofabrication, taking advantage of the Laboratory's unique facilities such as the Microelectronics Laboratory and Defense Fabric Discovery Center (DFDC). Projects in the portfolio are developing

- Physics-informed AI methods to accelerate the design and maturation of materials with innovative properties. The successful test of a microsystem for characterizing material arrays in a transmission electron microscope was a major step toward advancing historically slow experimental validation of new materials.
- High-quality, highly doped fibers for scalable high-energy laser sources. This work leverages the unique, all-halide doping system in the silica-fiber facility of the DFDC.
- Materials with high RF-radiation power to increase the range and detection of critical DoD systems. Toward this goal, researchers performed a thorough analysis of diamond/cubic-boron-nitride heterojunctions, developed the highest-quality diamond surfaces ever observed, and grew phase-pure cubic boron nitride in a custom growth reactor.
- A rechargeable battery in a textile-fiber form factor. The team demonstrated stable cycling of a zinc-ion battery, representing significant progress toward developing this technology, which will enable a new class of microelectronics no longer limited by the size and shape of their power sources.

Rich Molnar flame-polishes a silica-rod preform before it is drawn into optical fiber. The draw process will change the form of the rod to a submillimeter fiber stretching kilometers in length. Rare-earth elements such as ytterbium can be added into the core of the fiber to act as lasing centers. Other engineered glasses, such as aluminophosphate glass developed through this Technology Office program, are used to guide light down the fiber.

Critical Infrastructure Technologies

This investment supports foundational research and infrastructure development to meet national challenges in critical infrastructure protection and resiliency. These challenges include air and ground transportation; land border and maritime security; and DoD energy needs such as remote power, advanced energy storage, and in situ resource harvesting. Staff perform research in advanced sensors and architectures, signal processing, data fusion, and decision support, and develop prototypes and experimental test beds. Project highlights include

- A new machine learning approach for predicting airport capacity. This prediction methodology was demonstrated at 29 U.S. airports and presented at the Integrated Communications, Navigation and Surveillance Conference, where it received an award for best overall paper.
- Detect-and-avoid capabilities for the Massachusetts Department of Transportation (MassDOT) Aeronautics Drone Operations Program. This capability will aid MassDOT in conducting safe drone operations and developing operational concepts for beyond-line-of-sight flight. The program concluded with a flight demonstration in Lynn, Massachusetts, and will ultimately transition to a commercial vendor.

- Pathways to use activated aluminum as a fuel and as a reactant in other types of chemistry. Recent efforts have focused on using a special formulation of activated aluminum as a chemical filter to turn carbon dioxide in the atmosphere into a precursor for hydrocarbon fuel.

Laboratory researchers demonstrated a capability to map out winds in full 3D volumes by using a new spectral processing technique that approximately doubles the effective range of Doppler wind lidar systems. They disseminated their technique and results at the American Meteorological Society Annual Meeting in January 2024.

>> Investments in Emerging Technology, cont.

Biomedical Sciences and Technologies

Biomedical sciences and technologies research at the Laboratory focuses on biotechnology development, biomanufacturing, operationalization, and threat assessment; human and team performance enhancement and optimization; and advancement of diagnostics and therapeutics delivery for maintaining human readiness. Projects seek to develop advanced biomedical technology and systems to support national security, healthcare, and service member resilience and sustainability. Research and development in this domain is

- Developing AI-based methods and models to assist combat medics in austere environments. Staff created a taxonomy of retrieval-augmentation approaches, built a medical question-answering test bed to evaluate a large language model, and demonstrated the model's use for constructing medical knowledge graphs.
- Designing approaches for identifying biomarkers within human saliva to rapidly diagnose adverse cognitive health conditions, such as mild traumatic brain injury, post-traumatic stress disorder, and cognitive fatigue. This research could enable minimally invasive field tests for these conditions, with detection in less than one hour, to facilitate early intervention and treatment.
- Creating a generalized pipeline to identify, build, and characterize enzymes that can make biomanufactured building blocks. A cell-free protein expression and screening platform was established, focusing initially on the production and assessment of diiron oxygenase. This pipeline will provide an avenue to reduce the impact of supply chain issues and mitigate both safety and environmental concerns of DoD-relevant chemical production.

Biomedical Sciences and Technologies

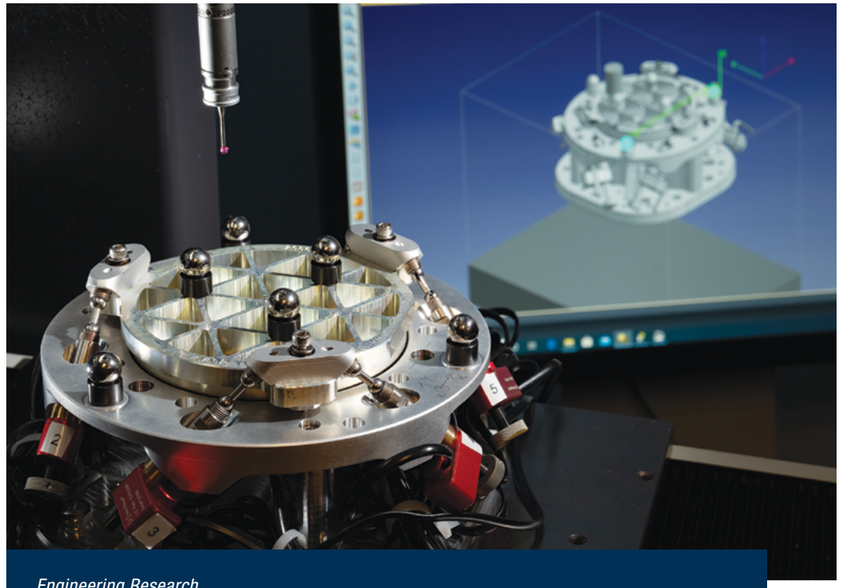
Medical Assistance Models with Verifiable Integrated Knowledge Program

The Medical Assistance Models with Verifiable Integrated Knowledge program aims to create a clinical AI assistant to improve information access on the front lines and elevate the quality of forward medical care in large-scale combat operations, which are expected to face medical personnel shortages in the future. Laboratory researchers are exploring how knowledge bases can integrate with retrieval-augmented language models to personalize delivery of verified clinical guidelines. In the 3D illustration shown at left, a medic interfaces with a clinical AI assistant on a handheld device.

Engineering Research

The Laboratory depends on state-of-the-art engineering capabilities to facilitate the development of advanced prototype systems. In the engineering research area, investments are made in new tools, processes, and technologies to enable improved capabilities with broad applicability to Laboratory mission areas and specific technology domains. In 2024, researchers

- Prototyped and tested a novel window mount for hypersonic seekers. The mount uses flexures to preload the window, allowing the window to survive the extreme thermal temperatures of a hypersonic environment.
- Demonstrated the ability to fabricate micro-optics with compound parabolic optical concentrators replacing microlens arrays. The optical concentrators offer superior light-collection capability for high-sensitivity systems.
- Developed a fast and accurate integrated multidisciplinary software tool to predict radar signatures of hypersonic vehicles.



Engineering Research

Multi-Element Freeform Optical Platform

Multi-element freeform optical designs offer unparalleled performance. However, the integration and alignment of elements in these designs can be challenging and often bottleneck the prototyping process. A self-aligning, electronically actuated six-degrees-of-freedom optical platform that interfaces with a machine learning neural network can vastly accelerate alignment for this class of systems. Here, an early prototype of the optical platform undergoes testing to characterize its accuracy, resolution, and range of motion.

Information Operations

The Laboratory has initiated research, development, evaluation, and deployment of prototype components and systems designed to improve the ability of the United States to counter adversaries in the information domain. This portfolio comprises ongoing projects that seek to

- Develop mission-relevant measures of effectiveness for information operations and demonstrate how such metrics can be used to assess and predict the impact of information operations, and develop courses of action to reduce that impact. A major achievement in 2024 was the development and demonstration of algorithms to predict future influencers and facilitate early detection of rising narratives.
- Understand the state of the art in AI generation and detection technologies applied to the operation of inauthentic online personas by malign foreign actors. To disrupt the ability of these personas to reach their target audiences, the Laboratory is developing mechanisms to detect personas and mitigate their impact quickly, accurately, and at scale. Over the past year, the team improved its automatic approaches for detecting author obfuscation and author impersonation.
- Design and build the Counter–Influence Operations Test Bed and Evaluation Range (CIOTER) to allow quantitative testing of tools, evaluation of human operator performance, and hosting of exercises. A key 2024 accomplishment was integration and use of CIOTER at several Office of Naval Research–sponsored influence-operation exercises to support data collection and analysis in real time and post event.
- Support the training and assessment of military operators tasked with developing and conveying messages to influence foreign group's attitudes and behaviors. The approach is to develop serious games that model the influence-operations process and to coordinate the use of these games by military operators as part of the training process. Key accomplishments in 2024 included development of a baseline version of the game, delivery of the game to U.S. Army Special Operations Command operators, coordination of several game-play events, and generation of requirements to drive future game enhancement.

The Psychological Operations Collaboration for Learning, Orientation, Practice, and Assessment project is developing a serious game to enable better training and operations methodologies for DoD information analysts. The tool gathers real-world information; selects an audience; and allows experienced operators to test, evaluate, compare, and contrast tactics and strategies.

ARTIFICIAL INTELLIGENCE AT THE LABORATORY

Lincoln Laboratory's commitment to advancing AI spans across its mission and technology domains, with the Technology Office taking a central role in coordinating Laboratory-wide AI initiatives

- The AI Technology Group has made significant strides in developing AI capabilities, including trusted AI, vanguard AI solutions, and interoperable software for rigorous AI model testing and evaluation. The group's focus areas include generative AI, large language models, and human–machine teaming, with applications in areas such as medical countermeasures and hypersonic technologies.

- Through the Department of the Air Force–MIT AI Accelerator (AIA), the Laboratory continues to collaborate with the Air Force and MIT to develop AI solutions for improving Air Force operations and addressing DoD needs. The AIA extended its original five-year collaborative agreement for another three years, with an option to continue for up to five more years. The AIA program comprises 15 AI research projects spanning a broad range of domains and applications, such as using AI to improve communications in cluttered electromagnetic environments, conduct autonomous drone search-and-rescue missions, support strategic diplomacy gaming, and autonomously fly fighter aircraft. Laboratory researchers hold leadership roles in all of the AIA projects.

- The Laboratory continues to develop innovative AI projects. One such project is leveraging large language models to enable humans to conduct after-action reviews with AI teammates, and another effort is accelerating materials discovery by developing a library for generation of material interfacial interactions and a deep digital twin for semiconductor deposition and etch.

Artificial Intelligence

Recent Advances in AI for National Security Workshop

The Laboratory hosted the sixth-annual Recent Advances in AI for National Security (RAAINS) workshop. The workshop underscored the urgent need for interdisciplinary collaboration on AI to address national security challenges and included courses on AI ethics, test and evaluation, and human–machine teaming.

Ana Smith, above center, presents her work applying graph structures to verify content authorship, one of several projects discussed during the RAAINS poster session.

At left, workshop attendees learn about the development of autonomy algorithms for small drones during a tour of the Autonomous Systems Development Facility.

INVESTMENTS IN INNOVATIVE RESEARCH

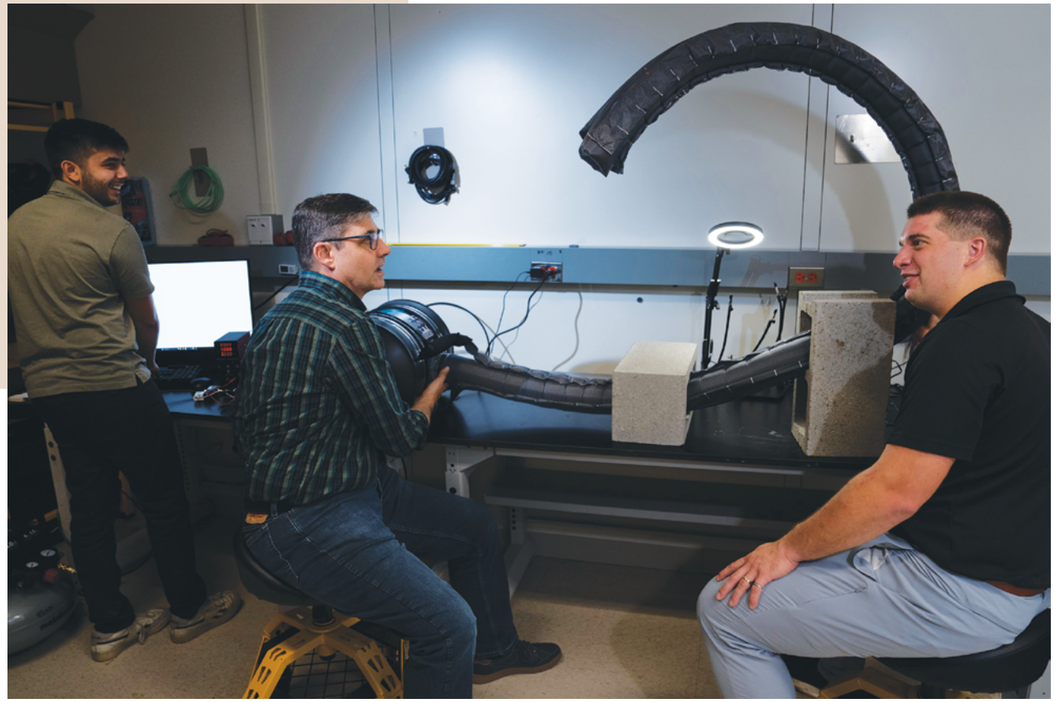
Providing support for R&D into foundational concepts and their applications in new systems

Seedlings

Through investments in Seedling projects, staff can pursue innovative technology ideas and feasibility demonstrations. Seedlings encourage exploration of radically new approaches and technologies that could benefit Lincoln Laboratory's mission space.

Advanced Concepts Committee

The Advanced Concepts Committee (ACC) provides funding and technical and programmatic guidance for the development of basic and applied technology concepts that address important technical problems. The ACC funds a breadth of highly innovative, high-risk research that, if successful, has the potential for significant impact on the Laboratory's mission areas.



Advanced Concepts Committee

Flexible Robot and Paired Sensory System for Search and Rescue

Urban search-and-rescue personnel must find, access, and extract trapped victims in hazardous terrain. In this Advanced Concepts Committee project, in collaboration with Professor Margaret Coad from the University of Notre Dame, Lincoln Laboratory researchers are developing a flexible robot and paired sensory system that can help with these tasks, allowing users to quickly and accurately navigate and map the difficult void spaces within rubble. From left to right, summer research intern Ankush Dhawan and Laboratory staff members Chad Council and Nathaniel Hanson test their robot in a laboratory setting.

FOSTERING INNOVATION AND COLLABORATION

Encouraging staff to discover and develop innovative technology by engaging in technical interchange meetings, conferences, seminars, and Technology Office challenges

Invited Speakers

In 2024, the Technology Office hosted several virtual and hybrid seminars aimed at sparking curiosity, creativity, and collaboration at the Laboratory. The seminars cover a range of topics and perspectives, and provide an opportunity for staff to learn about a new and interesting subject from a leading expert in the field.

MIT professor Oliver de Weck describes the critical elements to roadmapping strategies in his lecture, “Roadmapping the Future of Technology: In Space and on Earth.”

- Oliver de Weck, the Apollo Program Professor of Astronautics and Engineering Systems at MIT, discussed how to quantify technological progress and how to plan for future improvement through technology roadmapping and focused R&D investment.
- Aaron Sullivan, the Director of Hardware Engineering at Meta, shared his insights about how the pursuit of AI is influencing the world of silicon, systems, networks, data centers, software, and the people that make them.
- Chad Bouton, the Vice President of Advanced Engineering at the Feinstein Institutes of Medical Research at Northwell Health, presented work on how neuroprosthetic implants in the brain and AI can form artificial neural bypasses with the body and spinal cord to restore movement and sensation in persons living with paralysis.

Technology Office Challenges

Each year, the Technology Office invites staff to participate in challenges that explore topics relevant to the nation and the Laboratory’s mission areas. In 2024, the Technology Office hosted the 5T Casualty Care Challenge, which invited the Laboratory community to ideate around concepts to help address challenges of mass casualty care in austere environments. The 5Ts (triage, track, transmit, transport, and train) provided a broad scope to encompass many aspects of providing care after a mass casualty event: triage, medic and patient tracking, stabilization in austere conditions, communications in remote environments, and transport from initial stages through evacuation to distant hospitals. As part of the challenge, the Laboratory also invited government stakeholders to give seminars and provide their perspectives on the most pressing problems in this space. Through two phases of idea exploration and maturation, Laboratory staff generated compelling proposals across a broad spectrum. The winning idea, involving whole blood donations in the field, received seed funding to begin technology development.

CASUALTY CARE CHALLENGE

R&D 100 Awards

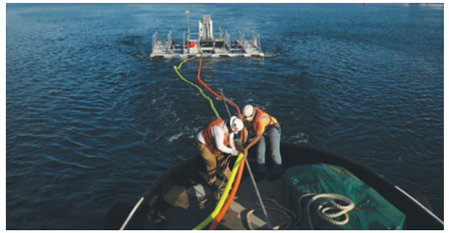
Team members gathered here represent the Laboratory’s 15 R&D 100 Award–winning technologies.

In 2024, *R&D World* magazine presented Lincoln Laboratory with 15 R&D 100 Awards for technologies developed either solely or in partnership with other organizations. The awardees are selected each year by an international judging panel composed of editors from *R&D World* and technical experts from academia, industry, and national laboratories. Since 2010, Lincoln Laboratory has received 101 R&D 100 Awards, including the technologies described below.

Autonomous Sparse-Aperture Multibeam Echo Sounder

A large sonar array, comprising a swarm of autonomous surface vessels, that uses estimation algorithms and acoustic signal processing techniques to rapidly generate high-resolution seabed maps

LINCOLN LABORATORY TEAM: Andrew March and Paul Ryu, project leads; Kevin Arsenault, David Brown, Thomas Burke, Byung Gu Cho, Phillip Daniel, Brian Day, Joseph Edwards, Edward Froehlich, John Glover, James Grasso, Paul Greenlee, Dori Hayes, David Kindler, Gerard LaJoie, Brian Lewis, David Lush, Edward Nunes, Paul Pepin, Katherine Rimpau, Jordan Rosenthal, Carrie Seiberling, John Stewart, Henry Wegiel, Allan Wirth, and Julius Zolotarevsky



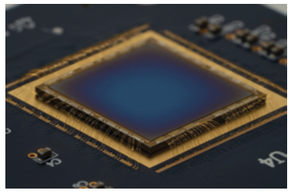
Electrooculography and Balance Blast Overpressure Monitoring System

A wearable system that provides early warning of blast-exposure risk for cognitive injury

LINCOLN LABORATORY TEAM: Jeremy Kemmerer and Christopher Smalt, project leads; Hrishikesh Rao and James Williamson

Engineered Substrates for Rapid Advanced Imaging Sensor Development

A fabrication process that reduces the time and cost of developing advanced silicon imaging sensors by enabling a straightforward back-illumination process and uniform thinning on small batches of detectors



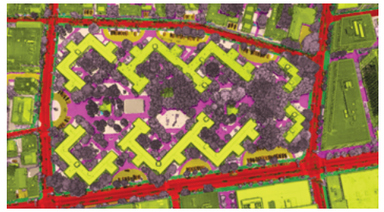
LINCOLN LABORATORY TEAM: Christopher Leitz and Kevin Ryu, project leads; Michael Augeri, Brian Aull, Sara Canzano, Joseph Ciampi, Rabindra Das, Erik Duerr, Brad Felton, Jonathan Frechette, Renee Lambert, Alex McIntosh, Steven Rabe, Daniel Schuette, and David Volfson

>> *R&D 100 Awards, cont.*

FocusNet

A machine learning architecture that performs context-driven automatic feature recognition and semantic segmentation of airborne ground-mapping lidar data

LINCOLN LABORATORY TEAM: James Kuczynski and Luke Skelly, project leads; Michael Chan, Robert Hatch, Jalal Khan, Diego Rivera, Ekaterina Sergan, and Alexandru Vasile



Heat Injury Prevention System

A wearable sensor system that monitors a person's heat injury risk, employing algorithms for estimating body temperature, gait instability, and adaptive physiological strain index

LINCOLN LABORATORY TEAM: James Balcius, Paula Collins, and Brian Telfer, project leads; Tara Boettcher, Nancy DeLosa, Joseph Lacirignola, and James Williamson

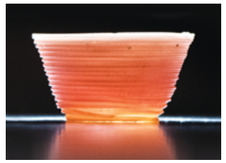
In-Band Full-Duplex Wireless System with Advanced Interference Mitigation

A wireless system that enables the mitigation of multiple interference sources, increasing the number of devices supported, their data rate, and their communications range

LINCOLN LABORATORY TEAM: Kenneth Kolodziej, project lead; Pierre-Francois Wolfe Heinz, Bruce McGuffin, Bradley Perry, and Scott Teal

Low-Temperature Additive Manufacturing of Glass Composites

An approach that uses a direct-ink-writing technique to extrude multimaterial glass ink into a desired form at room temperature

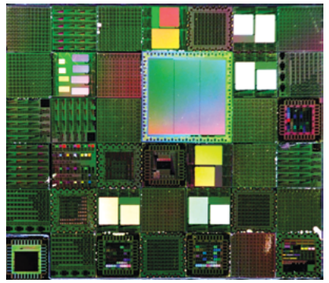


LINCOLN LABORATORY TEAM: Bradley Duncan, project lead; Devon Beck, Connor Belanger, Ryan Benz, Alberto Cabral, Eric Holihan, Keri Ledford, Vladimir Liberman, James McRae, Paul Miller, Livia Racz, Matthew Ricci, Caitlin Rock, Avery Rosh-Gorsky, and Melissa Smith

Megachips: Extremely Large-Area Integrated Circuits Constructed from Chiplets

An approach that interconnects small specialized chips into a monolithic integrated circuit, capable of reducing latency and energy costs for processing artificial intelligence data

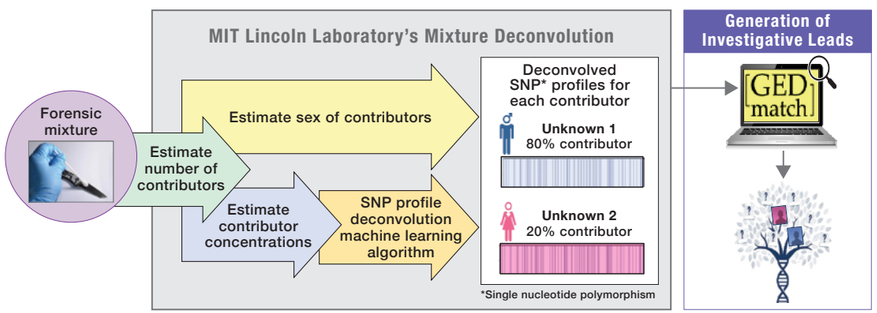
LINCOLN LABORATORY TEAM: Rabindra Das and Paul Juodawlkis, project leads; Jeffrey Birenbaum, Karen Harmon, Ryan Johnson, John Liddell, Christopher O'Connell, Jason Plant, Matthew Ricci, Kenneth Schultz, Marcus Sherwin, Matthew Stamplis, Christopher Thoummaraj, Brian Tyrrell, and Alexander Wynn



Mixture Deconvolution Pipeline for Forensic Investigative Genetic Genealogy

Software that allows analysts to decipher forensic samples containing DNA from two contributors without matching them to reference profiles, enabling search in commercial genealogical databases

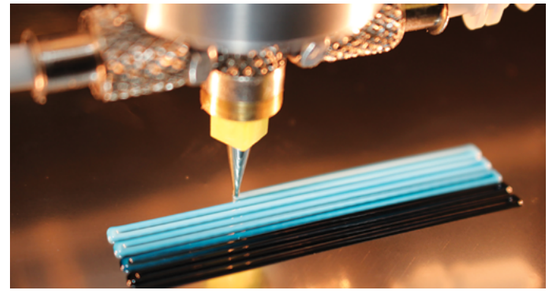
LINCOLN LABORATORY TEAM: Natalie Damaso, project lead; Philip Fremont-Smith, Chelsea Lennartz, and Adam Michaleas



Nanocomposite Inks for 3D Printing Radio-Frequency Devices and Radiation Shielding

A materials system and process that use specially tailored nanocomposite inks to additively manufacture radio-frequency devices with graded dielectric properties

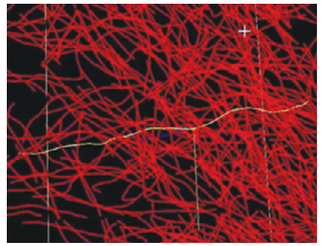
LINCOLN LABORATORY TEAM: Bradley Duncan and Theodore Fedynyshyn, project leads; Benjamin Barclay, Andrea Barney, Devon Beck, Ryan Benz, Jakub Bickus, Patrick Bluem, Salvatore Di Cecca, David Cipolle, Austin Coon, Michael Lis, Robert Longton, Paul Miller, Maxwell Plaut, Roberto Rojas-Teran, John Russo, Melissa Smith, and Andrew Zai



Neuron Tracing and Active Learning Environment

An end-to-end software pipeline that generates segmentations of neurons from large brain imaging datasets and allows expert validation from a web browser to enable semi-automated brain mapping

LINCOLN LABORATORY TEAM: Lars Gjesteby, project lead; Laura Brattain, David Chavez, Adam Michaleas, Benjamin Roop, and Michael Snyder



Portable Aircraft-Derived Weather Observation System

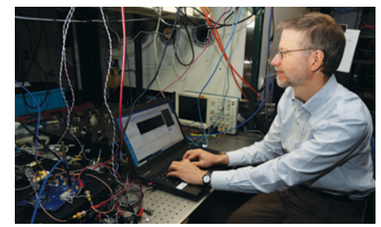
A system that significantly increases the number and quality of real-time wind and temperature observations from aircraft, enabling improved weather forecasting and climate monitoring

LINCOLN LABORATORY TEAM: Michael McPartland, project lead

Precision Photon Synchronization System for Quantum Networking

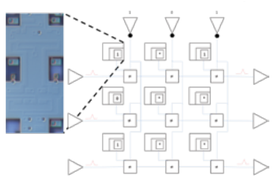
The first system that precisely synchronizes photons for long-distance free-space quantum entanglement distribution between different ground sites via an intermediary satellite

LINCOLN LABORATORY TEAM: Neal Spellmeyer, project lead; Don Boroson, Ben Dixon, Matthew Grein, Scott Hamilton, Nicholas Hardy, Catherine Lee, Ryan Murphy, Hemonth Rao, Marvin Scheinbart, Katia Shtyrkova, and Mark Stevens

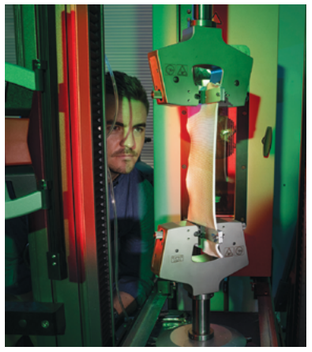


Superconductive Many-State Memory and Comparison Logic

The world's first superconductive circuits that natively store and compare greater than two discrete states, without significantly increasing the number of devices or surface area of the circuits



LINCOLN LABORATORY TEAM: Matthew Guyton, Chad Meiners, and Alexander Wynn, project leads; Evan Golden and Brian Tyrrell



Tunable Knitted Stem Cell Scaffolds

A biocompatible knitted material (scaffold) that advances cell regeneration by mimicking the mechanics of soft tissue to allow more successful stem cell therapy with fewer complications than achieved with current stiff scaffolds

LINCOLN LABORATORY TEAM: Erin Doran, Steven Gillmer, and Emily Holtzman, project leads; Robert Longton and Ariel Sandberg

TECHNOLOGY TRANSFER 57

Researchers deployed a rigid frame on which a technology demonstrator sparse sonar array was mounted for sea tests of the array's undersea-mapping capability.

Technology Transfer

THE TECHNOLOGY VENTURES OFFICE

The Technology Ventures Office (TVO) coordinates strategic technology transfers that maximize the impact of government-funded R&D in the commercial and government sectors.

TVO TEAM

(Left to right)

Jennifer Falciglia
Program Manager

Jordan Mizerak
Senior Technology Manager

Melly Coronado
Technology Manager

Asha Rajagopa
Chief Technology Ventures Officer

Joyce Pothier-Keenan
Administrative Coordinator

R. Louis Bellaire
Deputy Technology Ventures Officer

Teresa Fazio
Ventures Officer

Transfer of Lincoln Laboratory technologies into the commercial marketplace or operational use helps to maintain U.S. technological advantage. The TVO amplifies sponsor value by delivering the Laboratory's cutting-edge, defense-critical innovations to relevant national industries through several activities:

- Maintaining a web-based catalog of patents and software that enables government, commercial, and research communities to explore Lincoln Laboratory's technology solutions
- Partnering with researchers early in the technology development process to provide resources for technology incubation, acceleration, and translation
- Engaging with industry to assess commercial needs and guide companies to partner on matching technology solutions
- Collaborating with the broader technology transfer community to support federal laboratory initiatives and align with modern academic technology transfer priorities

FISCAL YEAR 2024 TECHNOLOGY TRANSFER BY THE NUMBERS

29
Patents issued

50
Patents filed

62
Invention disclosures filed

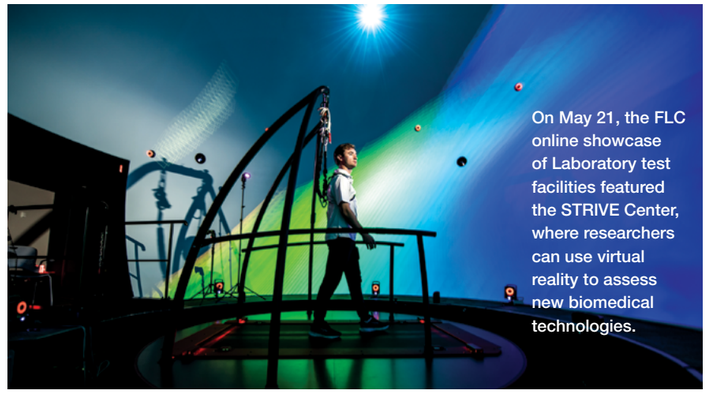
92
Software disclosures filed

SUPPORTING THE TECHNOLOGY TRANSFER COMMUNITY

The TVO's collaborations with external and internal communities engaged in technology transfer inform new and effective transition processes, help staff plan for eventual transfers, and generate expanded outside awareness of Lincoln Laboratory's available innovations.

Connection with the Federal Community

In recent years, the TVO has developed and strengthened a collaborative relationship with the Federal Laboratory Consortium for Technology Transfer (FLC) by leveraging the FLC's network and expertise to accelerate the transition of Lincoln Laboratory's innovative technologies into practical applications.



On May 21, the FLC online showcase of Laboratory test facilities featured the STRIVE Center, where researchers can use virtual reality to assess new biomedical technologies.

Beginning in April 2024, the TVO, in collaboration with the FLC, hosted a monthly online series providing comprehensive explorations into five of the Laboratory's premier facilities—Microelectronics Laboratory, Sensorimotor Technology Realization in Immersive Virtual Environments (STRIVE) Center, Optical Terminal Verification Testbed, Radio-Frequency Systems Test Facility, and Autonomous Systems Development Facility. These virtual events attracted more than 180 attendees from various government agencies, academia, and federal laboratories.

The TVO also helped spearhead nominations for FLC awards recognizing exemplary transfer of federally developed cutting-edge technologies. In 2024, Lincoln Laboratory earned a national Excellence in Technology Transfer Award for its efforts in transferring Timely Address Space Randomization (TASR)—a software developed to fill a high-priority gap in cybersecurity—to two commercial providers of cloud-based services.

At the 2024 FLC National Meeting in Dallas, Texas, principal investigator Hamed Okhravi, seen here with his poster on the TASR software, accepted the Excellence in Technology Transfer trophy.

Technology Transfer Awareness

The TVO Speaker Series

Internal and external guests are invited to present their transfer stories to help Laboratory staff understand the benefits of technology transfer. In 2024, Tom Roy presented on the transition of the TROPICS microwave sounder to commercial production, Charles Munson shared details of the Keylime cloud-security software transfer, and the AutonomUS team discussed commercialization of its robotic ultrasound device.

TVO Newsletters

A newsletter issued monthly to internal and external subscribers outlines patent activity and top Lincoln Laboratory news stories on technologies making fundamental improvements to their respective fields. The newsletter extends the Laboratory's reach to technology transfer communities nationwide.

FROM RESEARCH TO REALITY: LINCOLN LABORATORY INNOVATIONS IMPROVE LIVES

Prototype completion begins a technology's pathway toward maximum societal impact and value. The transfer of DoD–sponsored technology to industry strengthens national security, drives U.S. economic growth, and enhances the well-being of the nation's people. These examples highlight Laboratory innovations successfully providing real-world solutions.

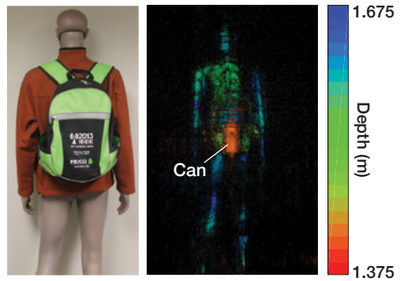
Safer Public Spaces Through Advanced Security Screening

Left, a person's seamless walk-through of a HEXWAVE™-equipped passageway immediately reveals potential threats concealed on the person.
Photo: Liberty Defense

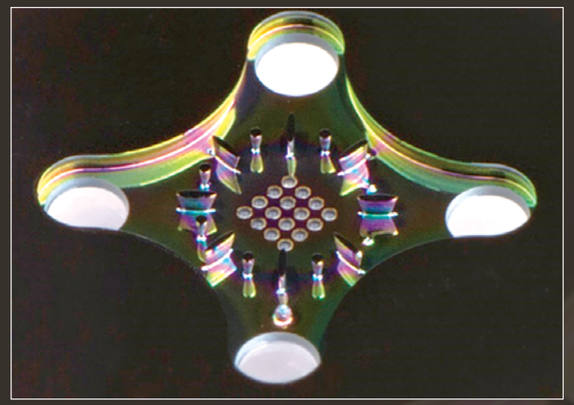
Below, the Laboratory's microwave imager captured this raster scan of a mannequin wearing a heavy winter coat and a backpack concealing a can.

Efficient, high-resolution imaging systems for concealed-threat detection are crucial for ensuring public safety in high-traffic areas such as airports, correctional facilities, government buildings, and stadiums. To be effective, these systems must enable real-time screening without disrupting traffic flow or compromising privacy. To address this need, Lincoln Laboratory developed a high-resolution microwave imager equipped with a multistatic array topology and advanced image-reconstruction algorithms. This innovative 3D millimeter-wave imager improved computational efficiency by two orders of magnitude over existing systems.

Through a Cooperative Research and Development Agreement with Liberty Defense, the Laboratory's microwave imager was integrated into the HEXWAVE™ security screening system. HEXWAVE™ revolutionizes threat detection by allowing individuals to walk through a screening area without stopping, removing items, or posing for scans—while upholding high standards of security and safety.



In 2024, HEXWAVE™ enhanced security at airports in New York and New Hampshire, and will be deployed in early 2025 at airports in Alaska, as part of the Transportation Security Administration's efforts to improve aviation employee and passenger screening. A Nevada courthouse has also chosen the system as its next-generation screening tool. Travelers passing through security checkpoints across the nation may soon experience the safety and efficiency benefits of this advanced security system.



Microjet cooling nozzles, embedded directly into an electronics device, can drastically improve heat transfer and allow for closely packed, high-power designs.

Next-Generation Computing Through Energy-Efficient Cooling Technology

With expanding computing capabilities come the challenges of managing the heat generated by advanced electronics. Traditional, bulky heat sinks inefficiently cool localized hotspots; consume excessive energy; and prohibit compact, high-performance designs. Next-generation computing and energy-efficient data centers demand innovative, efficient, and scalable cooling solutions.

This demand motivated Lincoln Laboratory's development of microjet cooling—a groundbreaking thermal-management technology. Recognized as a 2022 R&D 100 Award winner and now protected by multiple patents, this technology utilizes an array of small liquid jets that impinge on a heated surface within a microdevice. By operating as a single-phase system, microjet cooling delivers a 10-fold increase in heat transfer at a fraction of the size of traditional heat sinks.

In 2019, former Lincoln Laboratory researchers founded JetCool, leveraging the patented microjet cooling technology to advance thermal-management solutions. Since its founding, JetCool has forged strategic partnerships with industry leaders to redefine cooling technology. These collaborations have led to efficient, reliable, and scalable cooling systems for semiconductors and data centers, and a liquid cooling solution that improves cooling efficiency by 82% and reduces power consumption by 15% compared to conventional air-cooling systems.

Recently, JetCool was acquired by Flex, a global provider of design and manufacturing services, which plans to integrate the advanced liquid cooling technology into next-generation servers. This partnership is set to transform high-performance computing by solving the growing thermal demands of artificial intelligence (AI) and high-density workloads while improving energy efficiency.

TECHNOLOGY TRANSFER PATHWAYS

The TVO leverages distinct pathways to support transitions addressing critical national challenges, government objectives, and industry advancements: sponsor-directed transfers to commercial entities and external nongovernment organizations, direct-to-sponsor transfers to government agencies, and internal program-to-program transfers. Each pathway leads to maximizing the impact and applicability of Laboratory-developed technologies.

Sponsor-Directed Transfer

Sponsor-directed transfers originate from a sponsor's need to advance a Laboratory-developed innovation beyond the prototype stage. Technology is transferred to a commercial entity with an existing government contract for further development and production. In alignment with the sponsor's strategic objectives, this pathway advances a technological solution toward addressing critical national needs while ensuring government use rights are secured.

Direct-to-Sponsor Transfer

In a direct-to-sponsor transfer, Lincoln Laboratory provides technology directly to government sponsors or collaborating government agencies, ensuring seamless integration into national security and public safety frameworks. This pathway enables sponsors to rapidly deploy advanced systems and innovative tools, enhancing operational capabilities within existing government infrastructure and improving mission readiness and effectiveness.

Program-to-Program Transfer

Technology developed for a specific program and sponsor often transitions internally to other programs involving either the same or a different sponsor. These transitions maximize technology impact by advancing readiness level, improving design sophistication, and broadening applicability to address new challenges.

Transfer to the Field

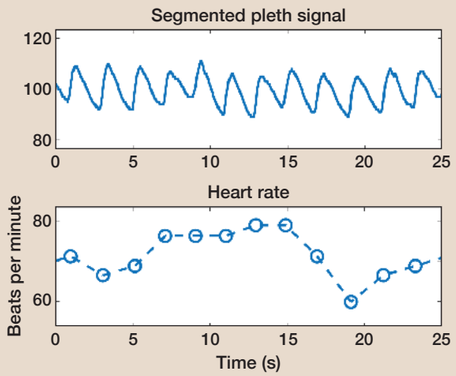
Stakeholder success is achieved when a technology advances from development to field deployment and operational use in real-world scenarios. Enabled by sponsor-directed, direct-to-sponsor, or program-to-program transfers, fielded technologies find applications in military operations, industrial processes, and public infrastructure. These deployments exemplify the practical value of R&D and often inspire iterative improvements through user insights.

Sponsor-Directed Transfer

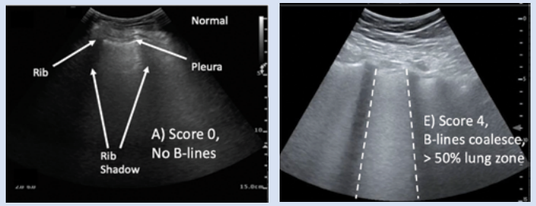
Case Study: Algorithms for Assessing Pilot Heart Rate and Physiological State

Unexplained physiological events (UPEs) can cause pilots to lose control, impairing their reaction times, situational awareness, and decision-making, and sometimes resulting in loss of life. While the root causes of UPEs are not fully understood, for pilots, the stress of frequent acceleration and deceleration, along with changes in oxygen intake and cabin pressure, can be contributing factors. Recognizing the importance of early warning of UPEs, U.S. Air Force sponsors sought a capability for assessing the physiological state of pilots during training. Lincoln Laboratory developed signal processing algorithms to analyze noninvasive photoplethysmography (PPG) data collected from sensors, installed on pilots' helmets, for monitoring the physiological state of pilots during flight. Under Air Force direction, these innovative algorithms were transferred to Spotlight Labs in combination with additional cockpit PPG metrics to provide pilots and their managers with an improved technique to gauge the health effects of high-speed flight.

Spotlight Lab's SPYDR sensor suite, incorporated into a pilot's helmet, gathered data for demonstrations of the algorithms that calculate physiological state.



The PPG (plethysmography, i.e., pleth) signals were collected during high-speed flights. The research team prioritized development of algorithms optimizing heart-rate measurements because heart rate is a key determinant of physiological state.



In chest ultrasounds, Lincoln Laboratory's AI-powered image-processing algorithms quickly detect and quantify B-lines, key indicators of pulmonary edema. The left image (Score 0) represents a normal lung with no B-lines, indicating no fluid accumulation. The right image (Score 4) shows coalescing B-lines covering more than 50% of the lung zone, signifying severe fluid accumulation.

Program-to-Program Transfer

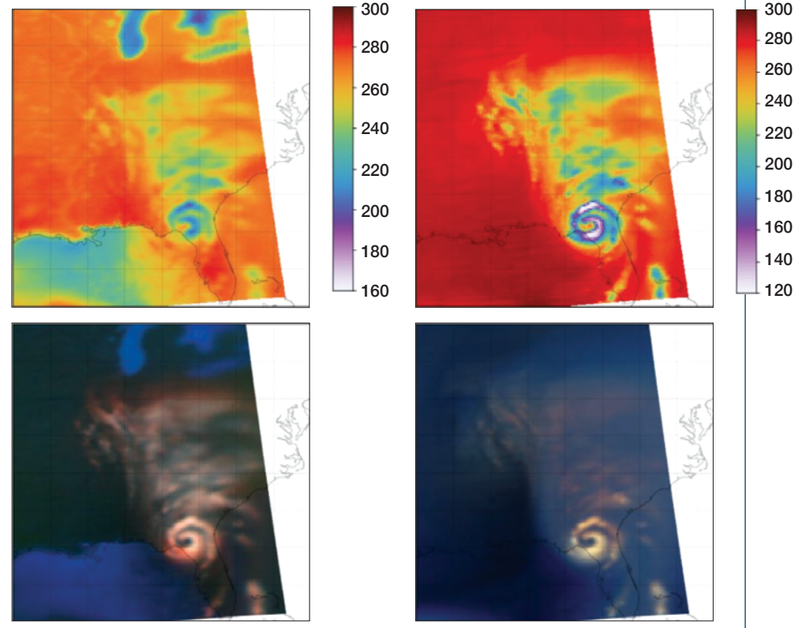
Case Study: AI for Diagnostic Imaging

Pulmonary edema, a condition in which fluid builds up in the lungs, can progress rapidly and is often diagnosed only after clinical symptoms worsen. Early diagnosis, typically via ultrasound imaging, is critical for appropriate interventions, but manual evaluation of ultrasound data is time-intensive and prone to evaluator variability. Lincoln Laboratory applied innovations from two programs to develop technology that automatically detects markers of fluid accumulation in chest ultrasound images. By pairing a semiautomated data pre-labeling algorithm with AI-powered image-processing algorithms, the researchers built software that provides improved sensitivity and image specificity to enable accurate and early diagnosis.

Transfer to the Field

CASE STUDY: Microwave Sounders for Storm Tracking

Tracking severe storms is essential for accurate forecasts, disaster preparedness, and public safety. To track rapidly evolving storms, multiple satellites can be used to take measurements more frequently, but existing satellite weather-tracking systems are large and expensive. To address this need, Lincoln Laboratory, with NASA and Laboratory funding, developed a miniaturized microwave sounder capable of collecting high-resolution atmospheric data. This sounder technology was transferred to Tomorrow.io, a Boston-based company, which is building a constellation of 18 CubeSats to cost-effectively track and predict severe storm behavior. Two of these sounders were launched in August 2024 and provided real-time tracking data of Typhoon Yagi and Hurricane Helene in September 2024, offering valuable insights into storm structure, intensity, and surrounding weather patterns.



Images of Hurricane Helene, captured by Tomorrow.io's Sounder 1 just after midnight Eastern Time on September 27, 2024, showcase various atmospheric data layers. Images: Tomorrow.io

TECHNOLOGY TRANSFER VIA BUSINESS COLLABORATIONS

Engagement with the commercial sector maximizes the economic and societal impacts of Lincoln Laboratory's federally funded R&D as industries and nonprofit organizations collaborate with the Laboratory to advance technology development or adapt innovations to their product development.

2024 INTERACTIONS WITH COMMERCIAL SECTOR		
Mechanism	**Benefits**	**2024**
Cooperative Research and Development Agreements (CRADAs) for dual-use or commercial technology development	Allows businesses and the Laboratory to collaborate on federal R&D while businesses can explore potential for leveraging the R&D	**23** CRADAs
Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) R&D partnerships with qualified small businesses on projects sponsored by diverse government agencies	Enables Lincoln Laboratory to contract with small businesses or nontraditional defense contractors in a fast, flexible, and collaborative manner	**39** SBIRs/STTRs
Commercial licensing	Promotes the development and timely delivery of commercial products that leverage innovative government-funded research	**5** commercial licenses and options
Collaboration agreements with nonprofit institutions	Advances early-stage technology development for a wide range of applications	**28** research collaborations
Open-source software distribution	Allows wide utilization of the Laboratory's software and fosters innovation via a collaborative community of users	**39** open-source projects

Enabling Future Autonomous Air Cargo Carriers

The Laboratory collaborated with Merlin Labs to develop the capabilities required by a nonhuman pilot to operate a diverse range of aircraft. This partnership draws on Lincoln Laboratory's significant strides in enhancing airport, terminal, and en route capacity and safety for both crewed and uncrewed aircraft. The Laboratory supplied the company with an Airborne Collision Avoidance System for Unmanned Aircraft (ACAS Xu) software library and provided support for its seamless integration and testing on the company's test platform. By leveraging a standardized interface, ACAS Xu was successfully embedded into the test vehicle, and the resulting integration and test data will be publicly disseminated through the Radio Technical Commission for Aeronautics (RTCA) standards process with publication of the revised standard plan for 2025. This technology transfer aimed to foster the development of essential standards that promote aviation safety, specifically by improving collision avoidance capabilities for future autonomous large cargo platforms within uncrewed air systems.

A Merlin "pilot" flight-test campaign was conducted at facilities in the Mojave Desert, California. Photo: Merlin Labs

Patents Granted to Lincoln Laboratory Inventors, October 1, 2023–September 30, 2024

Aluminum Slurry Fuels and Their Methods of Use
U.S. Patent 11,772,965; issued October 3, 2023

Ferrimagnetic Oscillator Magnetometer
U.S. Patent 11,774,520; issued October 3, 2023

Multilayered Microhydraulic Actuators
U.S. Patent 11,777,422; issued October 3, 2023

Surface Penetrating Radar and Battery Systems
European Patent 3,676,636; multiple countries; issued November 8, 2023
International Patent System ZL201880067177.X; issued April 12, 2024

High-Density Cryogenic Wiring for Superconducting Qubit Control
U.S. Patent 11,823,811; issued November 21, 2023

Data-Driven Angular Jitter Estimator for Lidar
U.S. Patent 11,830,194; issued November 28, 2023

SBS [stimulated Brillouin scattering] Suppression and Electronic Path Length Matching in Coherent Beam Combining
U.S. Patent 11,831,123; issued November 28, 2023

Aerial Vehicle with Tape Spring Arms
U.S. Patent 11,834,163; issued December 5, 2023

3D Printed Devices Formed with Magnetic Inks and Methods of Making Graded Index Structures
U.S. Patent 11,845,219; issued December 19, 2023

System and Method for an Optical Blood Flow Measurement
U.S. Patent 11,872,022; issued January 16, 2024

Additive Manufacturing of Composite Powders
U.S. Patent 11,872,631; issued January 16, 2024

Flow Through Fuel Reactor
U.S. Patent 11,884,543; issued January 30, 2024

FOVEA (Forensic Video Exploitation and Analysis) Tool
International Patent System 68,856; issued February 5, 2024

Broadband Diplexed or Multiplexed Power Amplifier
U.S. Patent 11,916,522; issued February 27, 2024

Extending Footprint for Localization Using Surface Penetrating Radar (SPR)
Ordinary Patent 40,017,240; issued April 5, 2024

Method and System for Localization of a Vehicle Using Surface Penetrating Radar
Ordinary Patent 40,017,347; issued April 5, 2024
European Patent 3,574,340; multiple countries; issued June 26, 2024

Multimaterial Fibers and Methods of Manufacturing the Same
U.S. Patent 11,951,672; issued April 9, 2024

Recovery and Recycling of Byproducts of Activated Aluminum
U.S. Patent 11,958,045; issued April 16, 2024

Adjustable Alignment Mount
U.S. Patent 11,971,606; issued April 30, 2024

Polarization-Separated, Phase-Shifted Interferometer
U.S. Patent 12,000,698; issued June 4, 2024

Multimaterial Fibers and Methods of Manufacturing the Same
International Patent System 4,139,510; issued June 5, 2024

Oscillator-Based Solid-State Spin Sensor
U.S. Patent 12,032,044; issued July 9, 2024

Methods and Apparatus for Passive, Proportional, Valveless Gas Sampling and Delivery
International Patent System 3,793,436; issued July 17, 2024

Systems and Methods for Genetic Identification and Analysis
U.S. Patent 12,065,696; issued August 20, 2024

High-Power Light Absorbers Having Anti-reflection Coating
U.S. Patent 12,066,679; issued August 20, 2024

Efficient Operations

In 2024, the Laboratory drove efficient operations forward by implementing new services, process upgrades, and partnerships. Efficiency improvements are spearheaded by the Business Transformation Office, Information Services Department, Efficiency Improvement Team, and subject-matter experts from across the Laboratory.

Improving the Business of Research

The Digital Enterprise Transformation (DET) is a multiyear effort to modernize Laboratory operations and improve efficiency. Objectives of the DET are to

1. Advance a culture of ownership, accountability, and continuous improvement within core operations processes
2. Equip Laboratory staff with new capabilities aligned with a digitally mature organization
3. Simplify core business processes
4. Use data-driven insights to inform decisions
5. Establish an enterprise architecture that is scalable and adaptable to changes in the operating environment

In 2024, progress on DET initiatives included the

Establishment of the Enterprise Capabilities Board. This cross-organizational decision-making body was established to align the Laboratory's strategic direction with operational investments. It was formed in part to address the modernization needs identified by groups and departments across the Laboratory. Consisting of leaders from service departments and technical divisions, the board will help evaluate, prioritize, and sequence the delivery of capabilities to drive value and improve outcomes.

Improvements to Human Resources (HR) processes. The HR Department implemented a framework, in line with best practices, for improving data collection, analytics, and reporting. A service platform using this framework is enabling hiring managers to monitor applicants by stages within the hiring process, evaluate open requisitions, view offer-acceptance ratios, and determine factors impacting the hiring-process timeline.

Management of workspace planning. Strategically designing, planning, and managing spaces within the workplace optimizes efficiency and functionality. The Space Management Modernization project is deploying an integrated workplace management system to converge workspace planning processes, align strategies, improve decision-making, and establish one source of truth for all workspace data.

Simplification of budgeting processes. To simplify, unify, and consolidate Laboratory operational budget planning and forecasting processes, the Laboratory is implementing a new software tool called OneStream. Once fully deployed, OneStream will facilitate budgeting of all Laboratory services, facilities modernization plans, and research operations costs.

Centralization of business support tools. Beyond fulfilling their primary research responsibilities, technical group leaders at the Laboratory are tasked with many critical functions, from managing financials and tracking projects to appraising personnel performance. The Group Office Portal is a centralized environment that aggregates the tools and data needed by group leaders to perform such tasks effectively. In 2024, the portal was upgraded to include a portfolio-analysis view with drilldown capability at the enterprise, division, group, and program levels.

Modernizing Facilities

In 2024, the Laboratory released a 40-year master plan of facility modernization projects. The plan was driven by the needs of the Laboratory's mission areas and staff community, promising spaces that are flexible to the dynamic nature of the Laboratory's work, organized for efficiency and collaboration, and sequenced to minimize interruptions to programs.

Projects funded by DoD investment include two new purpose-built R&D facilities: the Compound Semiconductor Laboratory – Microsystem Integration Facility, which is under construction and slated for completion in 2027, and the Engineering Prototyping Facility, which is in the design phase. Long-term projects will replace all of the Laboratory's aging buildings and expand its overall campus footprint. The end result will be a modern, sustainable, and connected Laboratory complex.

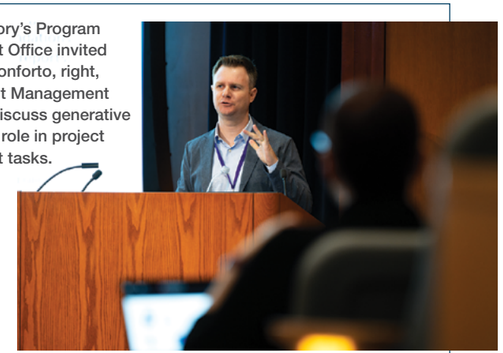
Personnel from Hanscom Air Force Base's Strategic Services Division and 66th Air Base Group joined personnel from MIT and Lincoln Laboratory to sign a modified prime contract that transitions land and property to the Laboratory. Photo: Mark Wyatt, U.S. Air Force

To enable the modernization plan, MIT signed in April 2024 a 50-year lease agreement and contract modification with Hanscom Air Force Base to transition more than 64 acres and 22 buildings from the base to Lincoln Laboratory.

The Facilities Modernization Plan report was published in 2024.

Enhancing Information Technology

- Advancements to security processes. In 2024, the DoD moved forward with the highly impactful Cybersecurity Maturity Model Certification program, and the Laboratory responded with an enterprise-wide commitment to meet information security requirements for this program. The Laboratory furthered its multifactor authentication requirements for networks, deployed privileged access management and other zero-trust protocols, and upgraded its system for continually monitoring a device's security posture.
- Improvements for collaboration. Collaboration tools and purpose-made collaboration rooms have continued to be rolled out to augment the hybrid workplace. The infrastructure and technology of the Laboratory's main auditorium was updated, creating a flexible and effective gathering space.
- Expansion of information technology (IT) services. Emerging generative artificial intelligence (AI) applications were researched, vetted, and made available to staff for use, facilitated by app training and technical support. A partnership was established with Gartner, a leading IT research and advisory company, to provide the Laboratory's IT staff with access to the latest technical research and expert advice. A new customer-relationship management tool was implemented to aid program efficiency. The Laboratory's intranet homepage was upgraded with a notification feature, helping staff stay on top of to-do items, and the Laboratory's emergency-notification system gained the ability to offer building-specific, staff-selected alerts.
- Enhancement to client-service capabilities. To help Laboratory employees quickly find IT solutions, AI tools were integrated into the IT service portal. A new portal was developed to streamline the process of locating and acquiring software.
- Upgrades to enterprise applications and devices. The Laboratory streamlined its virtual desktop infrastructure to offer an efficient user experience, and refreshed its enterprise network to ensure peak usability and security. The Laboratory's SAP Business Suite was migrated to a new cloud provider, and new Linux capabilities were offered. Customized enterprise-application solutions supported projects and processes across the Laboratory.

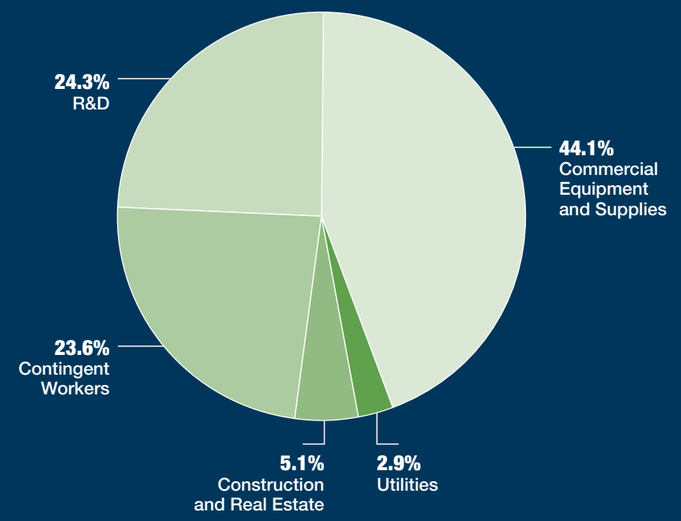


The Laboratory's Program Management Office invited Edivandro Conforto, right, of the Project Management Institute to discuss generative AI's growing role in project management tasks.

Economic Impact

Lincoln Laboratory serves as an economic engine for the region and the nation through its procurement of equipment and technical services. During fiscal year 2024, the Laboratory issued subcontracts with a total value of $536.3 million including businesses in all 50 states and Washington, D.C. While companies in Massachusetts were the recipients of the highest percentage of awards, businesses in states as distant as California and Texas also received substantial awards. The Laboratory also contracts with universities outside of MIT for basic and applied research. These research subcontracts include expert consulting, analysis, and technical support.

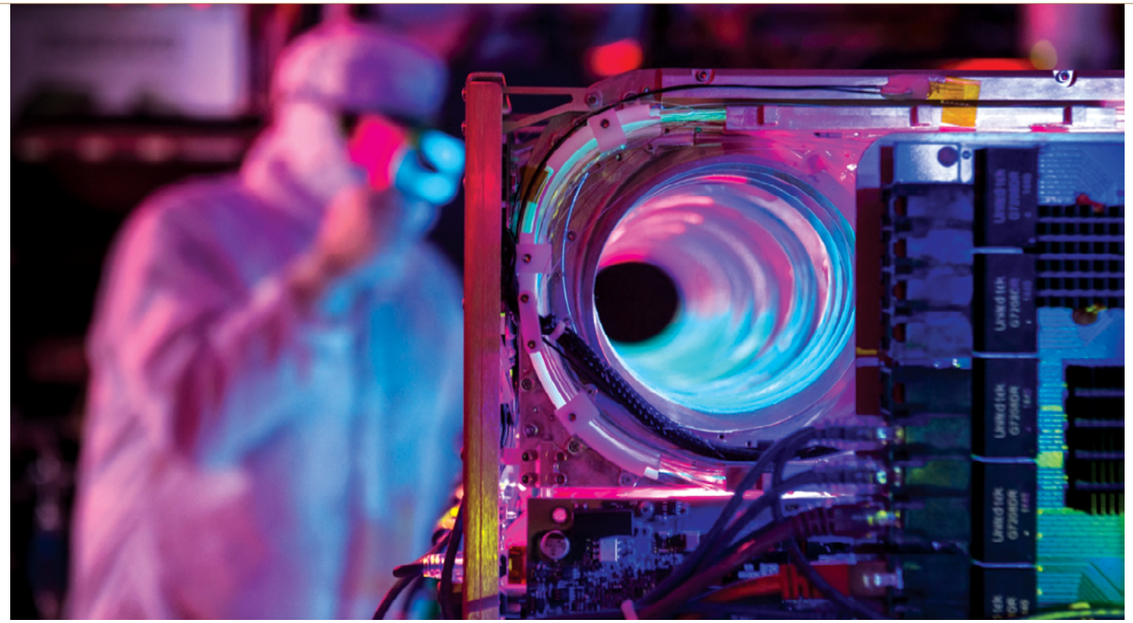
Procurement by Business Category (FY2024)



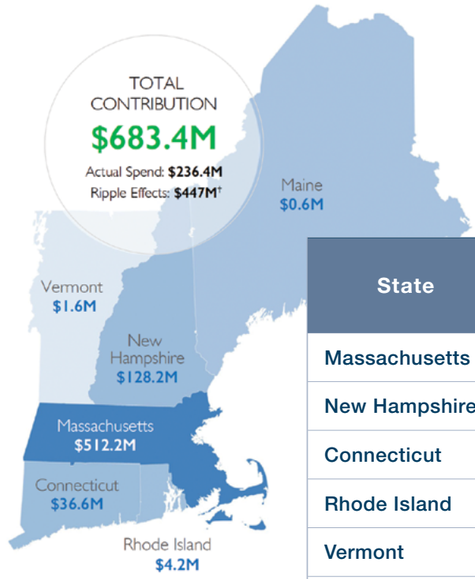
Top Procurement Awards by State (FY2024)

STATE	$ MILLION
Massachusetts	176.9
Virginia	76.7
California	69.9
Texas	45.9
New Hampshire	43.7
Connecticut	13.5
Maryland	10.9
All Other	98.8
Total*	536.3

**Includes orders to MIT – $10M*



The Contracting Services Department procures a variety of equipment to support research and enable system development at the Laboratory. Pictured here is a coherently combined laser system that demonstrated the highest brightness per unit mass in the world.



Economic Contribution to New England States

The Laboratory purchased $236.4 million in goods and services from New England companies, triggering $447 million in additional economic activity or "ripple effects" across the region, for a total regional economic contribution of $683.4 million. Ripple effects include regional business-to-business purchases along the supply chain, wages paid to industry employees, and consumer spending by industry employees.

State	Actual Spend $ (Millions)	Ripple Effects* $ (Millions)	Total Contribution $ (Millions)
Massachusetts	176.9	335.3	512.2
New Hampshire	43.7	84.5	128.2
Connecticut	13.5	23.1	36.6
Rhode Island	1.5	2.7	4.2
Vermont	0.6	1.0	1.6
Maine	0.2	0.4	0.6
Total*	**236.4**	**447.0**	**683.4**

*Source: IMPLAN application, IMPLAN Group, LLC.

LABORATORY INVOLVEMENT 71

Military students participating in the 2024 SOCOM Ignite program convene with Laboratory research mentors for the closing event. The annual program challenges students to innovate technology solutions for the U.S. Special Operations Command.

Research and Educational Collaborations

Microelectronics Commons Project Funding

The Microelectronics Commons, a $2 billion initiative of the CHIPS and Science Act, announced funding to the Northeast Microelectronics Coalition (NEMC) Hub for six microelectronics proposals, two of which include Lincoln Laboratory participation. White House and DoD officials announced the awards on September 18 during an event at Lincoln Laboratory.

"Ensuring U.S. leadership in microelectronics and semiconductor manufacturing is critical to our national and economic security."

Melissa Choi,
Lincoln Laboratory Director

Mark Gouker, assistant head of the Advanced Technology Division and NEMC Hub advisory group representative, described the Laboratory as being a key part of the Microelectronics Commons: "We have made strong connections to academia, startups, DoD contractors, and companies through collaborations with our technical staff and by offering our microelectronics fabrication infrastructure. We believe this tighter ecosystem will be important to future Microelectronics Commons programs."

Researchers at the Laboratory and on MIT campus will contribute to a quantum-photonic integrated circuit project. Collaborators include the Air Force Research Laboratory, Analog Photonics, Cornell University, Fermilab, Harvard University, IonQ, The MITRE Corporation, Spark Photonics, TOPTICA Photonics, University of Illinois Urbana-Champaign, Vapor Cell Technologies, and Yale University. Laboratory researchers will also participate in a project to develop a self-interference cancellation platform for radio-frequency systems with Sivers Semiconductors, BAE Systems, and Columbia University.

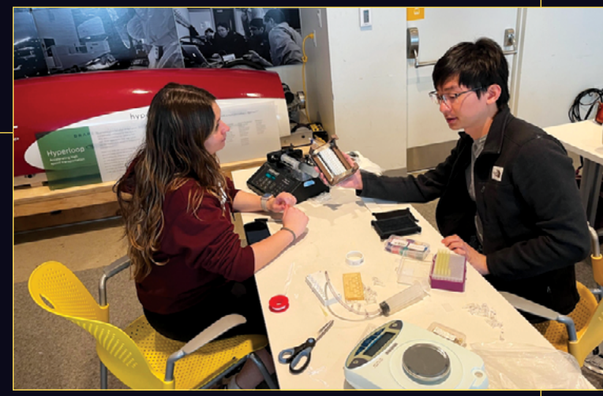
The funding comes amid the Laboratory's construction of the Compound Semiconductor Laboratory – Microsystem Integration Facility, which will complement the existing Microelectronics Laboratory. The facility is expected to play an important role in the greater CHIPS and Science Act ecosystem to strengthen U.S. leadership in semiconductor manufacturing and innovation.

Officials from the White House, DoD, Commonwealth of Massachusetts, and NEMC Hub visited the Laboratory on September 18 to announce federal funding for six advanced microelectronics projects in the northeast region.

Beaver Works

Student Research Program for Biosecurity

Lincoln Laboratory and the National Strategic Research Institute, a DoD university-affiliated research center at the University of Nebraska (NU), established a joint student research program. The goal of the program is to combine the scientific expertise, cutting-edge capabilities, and student capacity of NU and MIT to foster solutions in critical issues within global health and agricultural security.



MIT students Rachael Rosco, left, and Brandon Sun work on the droplet-dispensing manifold at the Beaver Works Center.

A pilot of the program was conducted within the MIT Engineering Systems Design and Development II course and hosted at the Lincoln Laboratory Beaver Works Center on MIT campus. The students' challenge was to develop methods to rapidly screen for novel biosynthetic capabilities. Currently, such methods are limited by the lack of standardized, high-throughput devices that can support the culture of traditionally uncultivable microorganisms. Twelve mechanical engineering students contributed to the program, prototyping and validating a gas-gradient manifold and a droplet-dispensing manifold.

These devices can simplify and accelerate the microculture of complex mixtures of organisms, allowing a user to dial in the optimal environmental parameters without the need for expensive hardware such as anaerobic chambers.

"The project was meaningful, and our work will hopefully make an impact. Who knows, maybe one day it will lead to cultivating extremophile bacteria on a foreign planet!" said Rachael Rosco, an MIT student in the program.

Robert Shin: A Legacy at Beaver Works

In 2024, Robert T-I Shin stepped down as the inaugural director of the Beaver Works Center after more than 10 years in the role. The success of Beaver Works, a joint center chartered by Lincoln Laboratory and MIT School of Engineering, can be directly traced to Shin's passion for strengthening the Laboratory's relationship with MIT campus. Shin co-led the initial study that created the Beaver Works concept and has been instrumental in sustaining the center, which has become a hallmark of the Laboratory's presence on campus since 2013.

Robert Shin addresses high school students participating in the Beaver Works Summer Institute, a staple of MIT and Lincoln Laboratory's educational outreach programming.

To enhance technical collaborations with campus, Shin initiated Beaver Works capstone classes with several MIT departments. Many of these capstones have led to startup companies, Laboratory prototyping efforts, and a growing cadre of MIT graduates pursuing national security careers. Beaver Works has enabled new research collaborations, such as the Department of the Air Force–MIT Artificial Intelligence Accelerator. Shin also founded the Beaver Works Summer Institute to foster high school students' interests in technology and engineering. He has since transitioned into a senior advisory role at Beaver Works.

>> *Research and Educational Collaborations, cont.*

From left to right, MIT LIDS team members Lukas Schmid, Nathan Hughes, Dominic Maggio, Yun Chang, and Luca Carlone pose with a quadruped robot that used Clio to grasp objects of interest. Photo: Andy Ryan

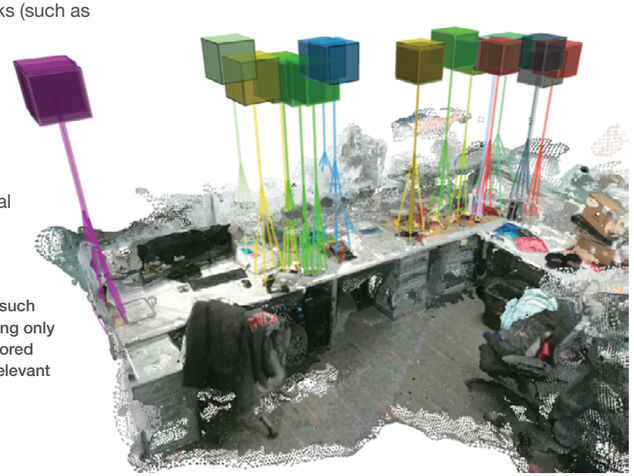
Robots That Ignore the Clutter

Lincoln Laboratory teamed with the MIT Laboratory for Information and Decision Systems (LIDS) to develop Clio: an algorithm-based system that enables robots to make intuitive, task-relevant decisions. With Clio, a robot takes in a list of tasks described in natural language and then determines the level of detail required to interpret a scene in order to complete those tasks.

In real environments ranging from a cluttered cubicle to a five-story building on MIT campus, Clio was presented with natural-language prompts such as "move rack of magazines" and "get first aid kit," and automatically segmented a scene at different levels of granularity accordingly. The team also ran Clio in real time on a quadruped robot. As the robot explored an office building, Clio identified and mapped only those parts of the scene that related to the robot's tasks (such as retrieving a dog toy while ignoring piles of office supplies), allowing the robot to grasp the objects of interest.

The researchers envision that Clio would be useful in scenarios requiring a robot to quickly make sense of its surroundings, such as in search-and-rescue missions. The team detailed their results in a study appearing in the journal *IEEE Robotics and Automation Letters*.

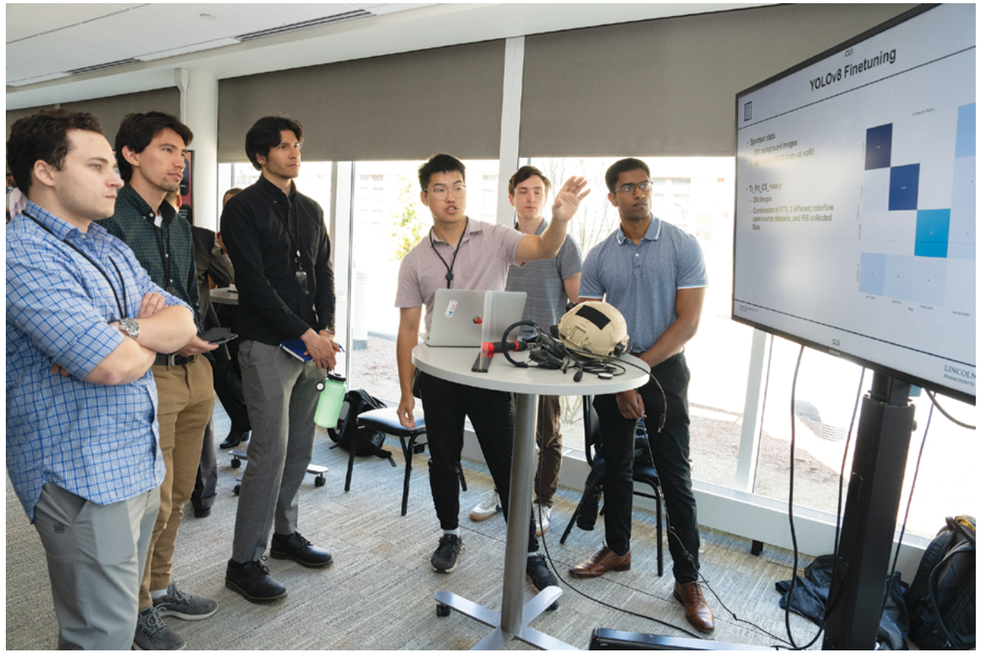
Adapted from *MIT News*



Clio quickly segments a scene such as this cluttered cubicle, focusing only on the segments (shown as colored cubes) that represent objects relevant to the task at hand.

Bioinspired Towed-Sonar-Array Design

In a study published in *Extreme Mechanics Letters*, researchers from the University of California, Berkeley, and Lincoln Laboratory demonstrated a way to potentially reduce excess noise in towed sonar arrays (TSAs). Noise compromises the sonar's detection signals and is often introduced when an array is dragged through water at high speeds. Inspired by Mother Nature, the researchers designed textured surfaces that mimic riblets, the unique patterns on shark skin. They used computational modeling to simulate various riblet surfaces for TSAs and the movement of water around them. Their results showed a reduction in drag and mitigation of flow-based noise, opening possibilities for more efficient TSAs in the future.



During the 2024 SOCOM Ignite tech expo, William Chu presents the artificial intelligence–enabled system for communicating a casualty's medical status and shares ideas for improving it in the next round of SOCOM Ignite.

Automated Casualty Status Tool

The Laboratory's U.S. Special Operations Command (SOCOM) Ignite program is an innovation pipeline that connects military students with research scientists and special operations forces to address pressing technology challenges. William Chu, a U.S. Army cadet from Rutgers University, served as the project lead on one challenge to develop a tool for communicating the medical status of casualties. The system uses artificial intelligence algorithms to automate the process of documenting a soldier's injuries, leveraging imagery and speech captured by a medic's helmet-mounted camera and microphone. This approach could save medics valuable time to perform lifesaving procedures, and allow status information to reach higher echelons of care before a casualty arrives. During the 2024 program's closing ceremony, the team won the SOCOM Ignite Award for Operational Impact. Today, Laboratory researchers continue to mentor students developing the system.

Research Into Nonverbal Communication

Nonverbal utterances are an important communication tool for non- or minimally speaking individuals. To date, little research has been done to detect and characterize the vocalizations produced by these individuals. A team spanning Lincoln Laboratory, Northeastern University, and the MIT Media Lab used advanced signal processing and analysis techniques to characterize categories of utterances, previously collected in a database, from seven individuals. This work could help researchers develop strategies and technologies to facilitate communication between non- or minimally speaking individuals and the people around them. A paper describing this research was published in the *Journal of Autism and Developmental Disorders*.

>> *Research and Educational Collaborations, cont.*

SkillBridge at Lincoln Laboratory

The DoD's SkillBridge program provides internships for service members to gain civilian work experience during their last six months of service. Last year, Josephine Lewis in the Human Resources Department brought SkillBridge to Lincoln Laboratory for the first time since the program's establishment in 2011. Since then, 40 service members have completed internships. More than half of those participants have transitioned into full-time roles at the Laboratory.

Connor Mathews, a U.S. Army cyber operations specialist, participated in a SkillBridge internship within the Secure Resilient Systems and Technology Group. He applied his experience "threat hunting," or analyzing secure communications data for signs of compromises, to a program that explored applications of steganography. The concept considered ways to encode covert messages into the source code of computer programs.

"Mathews' cyber operations experience in the Army was a major factor in helping us figure out what would look strange when attempting to construct programs with some covert effect," said researcher J. Parker Diamond. Mathews, who hopes to return to the Laboratory in the future, highly recommends the experience to other veterans.

Through a SkillBridge internship, Connor Matthews applied his experience identifying compromised communications to a research program on steganography. Photo: Joan Yox

U.S. Space Force members visit MIT Haystack Observatory in Westford, Massachusetts.

U.S. Space Force Collaboration

Members of the U.S. Space Force entered into a four-week collaboration with the Laboratory to better understand future space threats and the role of an FFRDC in supporting the DoD. Through this collaboration, Second Lieutenant Taylor Cannon, who works as an acquisition manager for the 1st Space Analysis Squadron, analyzed a potential capability gap and developed a proposed solution to bring back to her unit. Master Sergeant Charles Ezeike developed strategies to enhance the capabilities of the Space Force's aggressor squadron, which acts as a simulated adversary for training purposes.

Military Fellows Program

Active-duty military officers enrolled in graduate degree programs at Boston-area universities can engage in R&D at Lincoln Laboratory through its Military Fellows Program. Participants receive fully sponsored tuition and develop capabilities important to national security. The program pairs military fellows with Laboratory staff mentors, with mutual benefit: mentors provide technical expertise related to the fellows' areas of interest, while fellows provide firsthand perspectives on military technology needs. The 2024 cohort consisted of 26 fellows sponsored by 17 groups from across the Laboratory.

The U.S. Air Force Chief of Staff Gen. David Allvin, middle row, center, met with military fellows at Lincoln Laboratory on May 8. Allvin visited the Laboratory to learn about its research in wearable technology for military personnel.

As a fellow in the Laboratory's Cyber Systems Assessments Group, U.S. Air Force Maj. Minnenne Holloway helped conduct research on methods to effectively leverage modern technology, such as artificial intelligence (AI), for cyber operations. Her research focused on how AI tools can be used to counter information operations, and examining these tools at work in test scenarios allowed her to gauge their potential limitations in the real world.

"One of the big takeaways from my fellowship is what is within the realm of the possible as it relates to technology. This exposure will help me when I go into future operations," Holloway said.

Maj. Minnenne Holloway, U.S. Air Force

"The connective tissue formed by networking here will let me reach back to the Laboratory to address emerging challenges."

Second Lt. Katrina Thoms, U.S. Army

"The connections I make and the work I do will allow me to serve the military in the best way I can."

At the Modern Warfare Week symposium, Katrina Thoms, right, accompanied by SOCOM Ignite alumnus Jack Perreault, spoke about the Military Fellows Program. Photo: Global Special Operations Forces

U.S. Army Second Lt. Katrina Thoms's introduction to the Laboratory came through the U.S. Special Operations Command (SOCOM) Ignite program, an annual innovation challenge during which military students develop technologies that solve problems for the Special Operations Forces. Thoms participated in the program as a cadet. Upon returning to the Laboratory a year later as a military fellow, she mentored undergraduate students in SOCOM Ignite. During her fellowship, she acquired important skills such as summarizing research results in a concise and comprehensible manner, and tailoring explanations of technical concepts to an individual's interests. Thoms, who is studying applied behavioral analysis at Northeastern University, hopes to apply knowledge acquired from working as a mentor to research in human physiology and cognitive function.

"My work at the Laboratory is directly related to the work I hope to do in the future with the military. Understanding the value of innovation and seeing the big picture will help me as I move through my academic career. Being a mentor continues to teach me attributes of leadership," Thoms said.

>> *Research and Educational Collaborations, cont.*

Workshops and Seminars

Lincoln Laboratory hosts workshops and seminars where experts present research in emerging technologies. Such events synergistically benefit the military services, the broader government, federally funded research and development centers, and DoD contractors through peer interactions and idea sharing across organizational boundaries.

Department of Defense civilian employees and military officers attended the 2024 Defense Technology Seminar in March to discuss evolving military challenges. Guest speakers included USMC General David Berger (Ret.), Adam Berinsky and Kerry Emanuel of MIT, Sulmaan Khan of Tufts University, and Alexandra Vacroux of Harvard University.

2024 Schedule of Lincoln Laboratory Workshops

JANUARY

11 Human–Machine Teaming for National Security Workshop

MARCH

18–22 Defense Technology Seminar for Military Officers

APRIL

9–11 Advanced Technology for National Security Workshop

12 Defense Technology Seminar for U.S. Military Academy

30–1 MAY Homeland Protection Technologies Workshop

MAY

2–3 Geothermal Workshop

7–9 Space Control Conference

14–16 Air Vehicle Survivability Workshop

21–22 Lincoln Laboratory Communications Workshop

29–30 Cyber Technology for National Security Workshop

JUNE

4–5 Biotechnology and Resilient Human Systems Workshop

25–27 Air, Missile, and Maritime Defense Technology Workshop

SEPTEMBER

18 Civil Space Tech Expo

OCTOBER

8–10 ISR Systems and Technology Workshop

29–31 Anti-Access/Area Denial System and Technology Workshop

NOVEMBER

13–14 Advanced Prototype Engineering Technology Symposium

18–21 Recent Advances in Artificial Intelligence for National Security

DECEMBER

6 Defense Technology Seminar for Military Fellows

19 Climate Change Collaboration Accelerator Workshop

2024 Off-site Workshops

The Laboratory coordinates off-site workshops with partnering organizations. Laboratory involvement may be co-chairmanship of events or technical leadership of sessions. Many of the off-site workshops were offered virtually.

February 1–2
Next Generation Identification and Awareness Technology Workshop

February 20–27
Artificial Intelligence for Cyber Security

June 19
MultiEarth Workshop

July 16–17
Graph Exploitation Symposium

September 23–27
IEEE High Performance Extreme Computing Conference

October 15–17
IEEE International Conference on Wearable and Implantable Body Sensor Networks

November 5-7
Air Traffic Control Workshop

ENABLED Fabs Workshop

On October 2, the Laboratory hosted the first Extending Node Advancements by Leveraging Existing Domestic (ENABLED) Fabs workshop to make the case that U.S. fabrication facilities that manufacture 200-mm wafers and support chip capabilities for DoD applications lack the investment and support afforded to the leading-edge 300-mm wafer facilities. The workshop gathered technology owners like IBM, Texas Instruments, MIT.nano, and BAE Systems to identify common needs in the 200-mm foundry base which, if addressed, could advance the capabilities of the next generation of microelectronics systems. "It is critical to shore up domestic manufacturing of integrated circuits for facilities working on 200-mm wafers," said Dominick Pipitone. "This project will extend U.S. leadership in innovation."

Laboratory staff members Ryan Keech, left, and Dominick Pipitone, right, lead a group discussion at the ENABLED Fabs workshop.

Civil Space Tech Expo

A workshop participant discusses high-performance quantum magnetic microscopy with Laboratory researchers Danielle Braje, middle, and Jennifer Schloss, right.

In September, the Laboratory held its first Civil Space Tech Expo. The event follows the establishment in 2023 of the Civil Space Systems and Technology Office, which aims to leverage the Laboratory's dual-use technologies for civilian applications in space. The goal of the tech expo was to showcase prototype hardware and systems developed at the Laboratory and to connect with academic researchers who may be interested in collaboration. More than 100 exhibits showed a range of civil space capabilities, from remote sensing to quantum networking to resources in the Laboratory's Engineering Division.

Attendees enjoyed the chance to see what Laboratory employees are working on. Organizers Jennifer Falciglia of the Technology Ventures Office and Corrie Smeaton of the Optical Engineering Group plan to develop this expo into an annual event and include industry partners to expand opportunities for technology transfer.

Lincoln Laboratory Communications Workshop

The 14th annual Lincoln Laboratory Communications Workshop focused on spectrum operations, satellite communications, advanced network and communications systems, and laser communications. Talks included those on the Laboratory's space-based adaptive communications node, NASA's Deep Space Optical Communications project and ILLUMA-T mission, communications for the battlespace, the future of space data networking, and 5G coexistence. This year, attendees were also invited to join the first Space Warfighting Analysis Center Space Data Network Industry Day.

During an interactive poster session, staff presented their work on communications systems and engaged with workshop attendees.

Awards and Recognition

2023 MIT Lincoln Laboratory Technical Excellence Awards

Scott D. Coutts, for his creativity and leadership in developing and demonstrating novel signal processing capabilities and radar architectures and techniques, culminating in his rise to prominence in the field of high-frequency over-the-horizon radar.

Todd G. Ulmer, for his rich knowledge of free-space laser communications (lasercom), which has advanced four generations of lasercom systems at Lincoln Laboratory; for his contributions to lasercom standards; and for his commitment to transferring lasercom technology to industry in support of U.S. national defense.

2023 MIT Lincoln Laboratory Early Career Technical Achievement Awards

Steven R. Gillmer, for enabling the success of Lincoln Laboratory prototypes through his creative problem solving, technology innovation, and recognized leadership in the fields of optomechanics and precision engineering.

Cheryl A. O'Keefe, for her technical breadth and leadership in a wide array of rapid prototyping and system-level analyses spanning air superiority, space control, undersea sensing, missile defense, communications, acoustic sensing, and optical imaging.

2023 MIT Lincoln Laboratory Best Paper Award

Paul S. Ryu, **David D. Brown**, **Kevin D. Arsenault**, **Byung Gu Cho**, and **Andrew I. March** for their paper "A Wide-Area Deep Ocean Floor Mapping System: Design and Sea Tests," published in *Geomatics*, vol. 3, no. 1, 2023, pp. 290–311. Co-authors are Wael H. Ali, Aaron Charous, and Pierre F.J. Lermusiaux, all of MIT.

2023 MIT Lincoln Laboratory Best Invention Award

Kevin K. Ryu, **Brian F. Aull**, **Joseph S. Ciampi**, **Renee D. Lambert**, **Christopher W. Leitz**, **K. Alexander McIntosh**, **Steven Rabe**, **Daniel R. Schuette**, and **David Volfson** for their invention "Engineered Substrates for Rapid Advanced Imaging Sensor Development."

2024 AIAA Fellow

Katherine A. Rink was selected into the 2024 class of Fellows for the American Institute of Aeronautics and Astronautics (AIAA) for her leadership in developing critical capabilities in systems analyses, tracking, estimation, optimization, electronic warfare, and radar analyses that protect the nation from adversarial threats.

2025 AIAA Associate Fellows

Left to right, **Idahosa A. Osaretin** and **James C. Jones Jr.** were named Associate Fellows of the AIAA. Associate fellowships are awarded to individuals who have accomplished important engineering or scientific work and those who have made outstanding contributions to the field of aeronautics and astronautics.

2024 Optica Fellow

Bryan S. Robinson was named a 2024 Fellow of Optica for his extraordinary contributions to the advancement of satellite laser communications technology. Fellows are selected for exceptional contributions to the global optics community.

2024 Royal Aeronautical Society Fellow

Thomas G. Reynolds was named a Fellow of the Royal Aeronautical Society. The society is dedicated to driving innovation in aeronautical art, science, and engineering globally. Fellowships are awarded to individuals who have made outstanding contributions in an aerospace or aerospace-related profession.

2024 American Physical Society Fellowship

John Chiaverini received the 2024 Division of Quantum Information Fellowship from the American Physical Society for pioneering contributions to experimental quantum information science. Fellowship recipients are members who have contributed to the advancement of physics by independent, original research or who have rendered some other special service to the cause of the sciences.

Eric Evans receives Department of Defense Medal for Distinguished Public Service

In May, the DoD's chief technology officer, Under Secretary of Defense for Research and Engineering Heidi Shyu, presented Eric Evans with the DoD Medal for Distinguished Public Service. This award is the highest honor given by the Secretary of Defense to private citizens for their significant service to the DoD. Evans was selected for his leadership as director of MIT Lincoln Laboratory and as vice chair and chair of the Defense Science Board (DSB). During his tenure in both roles over more than a decade, Evans cultivated relationships at the highest levels within the DoD and advised eight defense secretaries and seven deputy defense secretaries.

Evans, right, accepts the award from Heidi Shyu, left, the Under Secretary of Defense for Research and Engineering.

Evans ensured that the Laboratory addressed not only existing DoD priorities but also emerging and future threats. He foresaw the need for and established three new technical divisions focused on cybersecurity, homeland protection, and biotechnology and human systems, and quickly pivoted the Laboratory to aid in the national response to the COVID-19 pandemic. He advocated for the modernization of major test ranges and secured funding for new state-of-the-art facilities, and strengthened research and educational ties with MIT campus. In parallel, he served on the DSB, the leading board for providing science and technology advice to DoD senior leadership.

Evans stepped down from his 18-year role as Lincoln Laboratory director in July. Now a senior fellow and professor of practice on MIT campus and a fellow in the Director's Office at the Laboratory, he continues to strengthen ties between the Laboratory and MIT campus and work with DoD leaders.

2024 Office of the Secretary of Defense Exceptional Public Service Award

Radha Plumb, left, of the Chief Digital and Artificial Intelligence Office presents the award to Streilein, right.

William W. Streilein received the Office of the Secretary of Defense Exceptional Public Service Award for his two-and-a-half-year appointment as the inaugural chief technology officer of the Chief Digital and Artificial Intelligence Office. The office was established in 2022 to accelerate DoD adoption of data, analytics, and artificial intelligence from the boardroom to the battlefield to enable decision advantage.

2024 National Academy of Engineering Election

Hsiao-hua K. Burke was elected as a member of the National Academy of Engineering for technology and leadership in remote sensing techniques and systems for ballistic missile defense and space systems. This election represents one of the highest professional distinctions in engineering.

2023 Society of Manufacturing Engineers "30 Under 30" Honoree

James Francis Nowak received the honor from the Society of Manufacturing Engineers. Honorees are selected for their professional impact and their engagement with both the manufacturing industry and their own community.

>> *Awards and Recognition, cont.*

2024 Top 50 Women Chief Technology Officers

Heidi C. Perry was named among the top 50 women chief technology officers by Women We Admire, an organization composed of the most accomplished women executives and leaders across the United States and Canada. Those chosen are visionary leaders at the forefront of technological innovation, steering their organizations through the complexities of the digital age.

2024 Excellence in Technology Transfer Award

Lincoln Laboratory received an Excellence in Technology Transfer Award from the Federal Laboratory Consortium for the Timely Address Space Randomization (TASR) software package. This cybersecurity technology, designed to harden cloud-based servers and user applications against rampant information-leakage attacks, was transferred in 2019 and 2021 to two companies that develop cloud-based services. Left to right, David Bigelow, Hamed Okhravi, and Jason Martin display the TASR software package they co-developed at Lincoln Laboratory.

2024 Herman R. Salmon Technical Publications Award

Thomas A. Washington received the 2024 Herman R. Salmon Technical Publications Award for his paper "A Method for Identification and Correction of Altitude Errors for Special Mission and Research Aircraft." The Society of Experimental Test Pilots grants this award to the best article published in *COCKPIT Magazine* during the year.

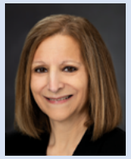
2024 Oklahoma State University Lohmann Medal and Hall of Fame Induction

Joseph P. Campbell Jr. received Oklahoma State University's Melvin R. Lohmann Medal and was inducted into the College of Engineering, Architecture and Technology Hall of Fame. The Lohmann Medal honors alumni for their contributions to the profession or education of engineers, architects, or technologists.

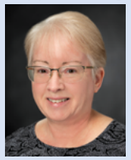
2024 MIT Excellence Awards

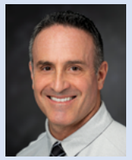
Bringing out the Best: **Salvatore Ieni**;
Outstanding Contributor: **Andrew H. Mack**

2024 MIT Lincoln Laboratory Administrative and Support Excellence Awards



Administrative category: **Paula Bolognese**, far left, for navigating many aspects of operations, including Human Resources, talent acquisition requests, facility needs, purchasing management, new employee technology acquisition/set up, and financial management; **John J. O'Rourke Jr.**, left, for his technical innovation and expertise on designing, building, and implementing information systems that support field-site radar applications while conforming to information security requirements.





Support category: **Debi A. Corcoran**, far left, for her contributions to the Secure Resilient Systems and Technology Group, where she consistently goes above and beyond to support the group in large and small ways that culminate in her having an enormous positive impact on overall group operations; **John Liddell**, left, for his 14 years of commitment and service to Lincoln Laboratory to support fabrication of semiconductor devices and his contributions to the growth and success of integrated photonics.

Toastmasters President's Distinguished Status Award

Lincoln Laboratory's **LLSPEAKS** club, a chapter of Toastmasters International, was presented with the President's Distinguished Status Award, the highest distinction a Toastmasters club can earn. Toastmasters is an international nonprofit educational organization that teaches public speaking skills through a network of clubs that meet online and in person.

2024 Disability Inclusion Award

For the second consecutive year, **Lincoln Laboratory** was recognized by the nonprofit Disability:IN as one of the best places to work for disability inclusion. Disability:IN is the leading resource for business disability inclusion worldwide. Their Disability Equality Index has become the standard for measuring the effectiveness of a company's policies, procedures, and accessibility programs in offering opportunities for individuals with disabilities to thrive and succeed within the organization.

2024 HIRE Vets Platinum Medallion Award

Lincoln Laboratory was awarded the Platinum Medallion Award by HIRE Vets in 2024. This award recognizes companies committed to recruiting, employing, and retaining our nation's veterans. This year represents the first that the Laboratory has received the Platinum Award, after earning the Gold Award for four consecutive years.

"Above and Beyond" Award for Employer Support of the Massachusetts National Guard and Reserve

Lincoln Laboratory was honored by the Employer Support of the Guard and Reserve, a DoD agency, for extraordinary support of employees who serve in the Massachusetts National Guard and Reserve. The award was created to recognize U.S. employers who go above and beyond the legal requirements of the Uniformed Services Employment and Reemployment Rights Act.

2023 Superior Security Rating

The U.S. Air Force awarded **Lincoln Laboratory** with a Superior Security Rating for the 18th consecutive year. The rating represents the Laboratory's commitment to safeguarding sensitive and classified information.

2024 Cultivating Leadership, Achievement, and Success (CLAS) Awards

Employee Resource Group Excellence Award: **Stephen A. Li-Tyson**

Equity Award: **Mary Grace M. Hager**

Outstanding Mentor Award: **Ryan A. Allured**

Leadership Award for Advancing Organizational Culture: **Michael Greenidge**

Peer Award for Cultural Impact: **Maria C. Bieri**

Best in CLAS Award: **Cheryl M. Bartolone**

Strength in Unity Award: Staff from Lincoln Laboratory Women's Network Know Your Worth Team: **Rituparna Basu**, **Kelly P. Beattie**, **Iva DeNicola**, **Marie L. Dow**, **Marina Lana Brazer Furbush**, **Ken A. Gould**, **Tyler T. Hamer**, **Raul D. Harnasch**, **Erica I. Landreth**, **Rowena J. Lindsay**, **Victoria C. Loehle**, **Heather L. Morris**, **David A. Radue**, **Divya G. Shastry**, and **Ana-Maria Mandrila Vacca**.

SASE Government Organization of the Year

The Society of Asian Scientists and Engineers (SASE) selected **Lincoln Laboratory** as the recipient of their prestigious Government Organization of the Year award. The award recognizes the Laboratory's significant advancements to science and engineering and its commitment to culture in the workplace.

Laboratory staff who attended the ceremony gathered for a photo together with Laboratory Director Melissa G. Choi, center.

People and Culture

Engaged and Accountable Leadership

Maximizing organizational benefit takes the proactive support of management and involvement of leaders from across the Laboratory. Lincoln Laboratory has three senior-level resource teams dedicated to furthering the organization's goals:

- The Executive Council provides strategic oversight, organizational support, and accountability for cultural transformation at the Laboratory. The council is composed of 15 representatives from different divisions, departments, and offices.
- Representing each division and department, the Champions are subject-matter experts who serve as liaisons helping to coordinate initiatives across the Laboratory.
- The Executive Sponsors for ERGs are leaders, mentors, or strategists within an ERG who provide advice and shape pathways for fostering an environment of belonging across the Laboratory.

The Laboratory seeks to maximize individual and organizational performance and effectiveness by incorporating holistic operations across people, business, and R&D systems and processes. Solving the nation's hardest problems takes the combined talents and unique views of many people; therefore, the Laboratory fosters an environment where employees feel they belong and can perform at their best. Employees are offered many resources and events, including leadership development seminars and Laboratory-wide educational and cultural initiatives.

Professional Development Opportunities

The Partnership, Inc.

The Partnership, Inc. offers leadership development programs and consulting services for organizations in all sectors.

The Conference Board

The Conference Board (TCB) is a nonprofit organization that focuses on business and business management–related research. This industry-leading research center aims to deliver independent and nonpartisan insights that will help businesses solve challenges. Lincoln Laboratory holds a TCB membership that provides Laboratory leaders with opportunities for personal and professional development outside of the organization. Laboratory TCB members have access to resources including publications, conferences, industry experts, webcasts, podcasts, roundtable discussions, working groups, and an online member community.

Human Capital Center

One of five United States–based centers of the TCB, the Human Capital Center provides members with guidance, support, and actionable solutions for optimizing human capital strategies to attract, develop, and retain employees while building a more effective and welcoming work culture. The Laboratory became a member of the Human Capital Center so that its leaders could gain insights about best and emerging workplace practices and how they can be leveraged to support the mission and vision of the Laboratory.

SynERGy

The Laboratory hosted SynERGy in April. This symposium brought together leaders to share their experiences, learn from each other, and build connections. Cross-organizational panel discussions focused on the evolution of ERGs and their strategies, and lightning talks highlighted ERG success stories with examples of engaging organizational events and initiatives. In the future, the Laboratory aims to establish regular virtual meetings between ERGs from different organizations and to hold the symposium annually.

Massachusetts Conference for Women

In December, Laboratory members attended the Massachusetts Conference for Women, sharing their work and life experiences, connecting with and inspiring each other, and building professional skills. During workshops and seminars, attendees discussed issues including personal finance, business and entrepreneurship, health, and work-life balance. The conference featured keynote speeches delivered by basketball player Caitlin Clark, Olympic athlete Gail Devers, model and actress Beverly Johnson, television anchors Gayle King and Robin Roberts, talk show host Oprah Winfrey, and others.

EmERGe Conference

In 2024, Laboratory ERG leaders and members attended the Seramount EmERGe conference, one of the only conferences in the nation that focuses on best and emerging practices for ERGs and their leaders. The conference offered training sessions, workshops, and educational seminars to help attendees maximize the impact of their ERGs. Academic scholars and leaders delivered keynote speeches about various challenges in society and the workplace. Working group sessions brought together ERG leaders from different organizations to network and exchange ideas.

Simmons Leadership Conference

Attendees of the 2024 Simmons Leadership Conference listen to a keynote speech at the Hynes Convention Center in Boston, Massachusetts.
Photo: Simmons University

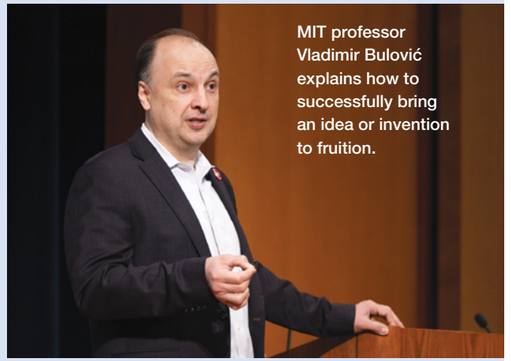
Laboratory staff joined thousands of leaders at the 45th Annual Simmons Leadership Conference in April. The Laboratory encourages its employees to attend this conference to develop their leadership skills, network with leaders from other organizations, and find inspiration from the keynote speakers. This year's speakers included author and consulting firm owner Cassandra Worthy, comedian and television show host Trevor Noah, and journalist and activist Gloria Steinem. The conference's theme was "creating impact," centering around the vision of reshaping workplace cultures. Attendees engaged in discussions surrounding this theme and received tools and actionable advice.

>> *People and Culture, cont.*

Cultivating Leadership, Achievement, and Success Symposium

Cultivating Leadership, Achievement, and Success (CLAS) is an annual Laboratory-wide symposium focused on fostering leadership, personal and professional development, and success in an inclusive environment to ensure that all Laboratory community members have the tools, resources, and support they need to thrive. The theme for this year's symposium, which was held from March 12 to 14, was "Success Through Failure."

Retired Gen. Ellen Pawlikowski holds a discussion with the Laboratory community about the importance of taking risks during projects.



MIT professor Vladimir Bulović explains how to successfully bring an idea or invention to fruition.

In a "fireside chat" with retired U.S. Air Force Gen. Ellen Pawlikowski, moderated by Lisa Basile of Lincoln Laboratory, Pawlikowski discussed Air Force technology development efforts in which she was involved, including the Airborne Laser and the Transformational Satellite Communications System. For each of these efforts, she explained lessons learned from the risks that were taken, the consequences of taking those risks, and the consequences of not taking risks in general. Pawlikowski also shared the challenges and opportunities she experienced as the third woman to achieve the rank of general in the Air Force.

The closing keynote speech was delivered by Vladimir Bulović, a professor of electrical engineering at MIT and the director of MIT.nano. Bulović's presentation, "Innovation Translated," described the process through which inventions transition from the laboratory to the outside world where they are used by millions of people. He also gave tips and step-by-step instructions for successfully executing an innovative plan, using real-life examples such as the Apollo missions to the moon.

Leadership Offsites for New Leaders

In December 2023 and January 2024, the Laboratory offered six one-day professional development offsite sessions for 112 new assistant group leaders, senior staff, and other leaders. The offsites sought to

- Help attendees understand different leadership styles and ways to adapt them to the Laboratory's culture
- Explore the connection between emotional intelligence and leadership effectiveness
- Educate attendees about intercultural competence (the ability to collaborate effectively with people from different functional, generational, and other backgrounds)
- Highlight awareness of individual experiences
- Inspire collaborative action among staff to advance the organization

Subject-matter experts facilitated the offsites, and attendees discussed focus topics. After the offsites, attendees received summaries of findings that resulted from the discussions.

Educational Initiatives

Fostering the next generation of engineers is important to the Laboratory's mission. Each year, talented students from universities around the nation work as interns at the Laboratory, contributing to national security R&D.

Summer Intern Spotlight: Brair (Tilboon) Elberier

What did you work on during your internship?

I was tasked with two major projects in the Homeland Sensors and Analytics Group. The first project was based on implementing a computer vision and image processing pipeline for drone target identification and tracking. In addition, I worked on implementing target state-estimation capabilities in the form of a Kalman filter for target reidentification in the case of tracker failure. The second project was to develop the hardware and software for a handheld, through-obstacle, presence-of-life-detecting radar that will be used by rescuers in critical situations.

How would you describe your internship experience?

My internship has been incredibly fulfilling and eye opening in multiple ways. I come from a background with no exposure to graduate school, specifically PhD programs, so working at the Laboratory provided me with invaluable insights into the diverse paths that graduate education can offer and the various contexts in which my work can be applied. Moreover, I had the opportunity to learn from colleagues with diverse research specialties, providing me with new perspectives that I plan to integrate into my future research. This experience has been invaluable for my development as an individual and as a researcher in academia.

What was a highlight of working at the Laboratory?

The standout aspect of my internship at Lincoln Laboratory has been the people. The unique culture here blends academic rigor with a genuine openness to diverse perspectives to attack problems in novel ways. I've been impressed by how members of the Laboratory value and engage with each other's ideas and interests, creating a supportive environment where everyone is eager to assist and collaborate.

>> *People and Culture, cont.*

Summer Intern Spotlight: Marc Alenn Jean Mary

What projects did you work on over the summer?
I worked on two laser communications programs. I like to describe it as working on two sides of the same coin: One program looked from Earth to space, while the second program looked the other way around. I had the pleasure of diving deeper into several topics, ranging from vibrations to optics, with staff who are experts in those fields.

I learned through a variety of tasks, each highlighting a different topic. For instance, one task focused on random vibrations. The project wanted to test how well vibration isolators would perform on a space optical assembly during launch. I faced the challenge of designing a test fixture stiff enough to not react over a certain range of frequencies to avoid inducing vibrations and skewing test results. Another task focused on protecting laser parts from water damage. I made a model of an optical component for the Earth-to-space communications project to test how a new kind of gasket would handle heavy rain.

How would you describe your internship experience?
It was educational and inspiring. Seeing the interesting areas that other interns and employees were working on showed me how far we have come with technology and inspired me to help push us further.

What was a highlight of being at the Laboratory?
The community of Laboratory employees and other interns really made this experience special. I am glad to be calling many people I have met here my friends and look forward to seeing the great things they will achieve.

Did you participate in any activities for interns?
Yes, I participated in I3C [Intern Innovative Idea Challenge]. My team wanted to tackle the renewable energy sector and came up with two ideas: a kinetic tile system and an escalator that uses a regenerative braking capability to lower people while harvesting their potential energy. Our ideas unfortunately did not make it past the first stage, but meeting new people and hearing all of their innovative ideas was a blast.

ERG Initiatives

Lincoln Laboratory ERGs provide cultural learning experiences and resources that help employees thrive in the workplace. Highlighted here are a few events organized by ERGs in 2024.

Conversation with Clemmie Whatley

The Laboratory hosted a series of events for its community. One of these events included a talk with Clemmie Whatley, an educator, an author, and one of the first Black female graduates of the Georgia Institute of Technology. Addressing Laboratory attendees through a Zoom webinar, Whatley discussed career obstacles and her journey to success, and provided advice to young professionals. She also showcased the importance of having support systems outside of one's workplace and shared her passion for nurturing the next generation of scholars and teachers through teaching mathematics at high school and university levels.

New Employee Onboarding Guide

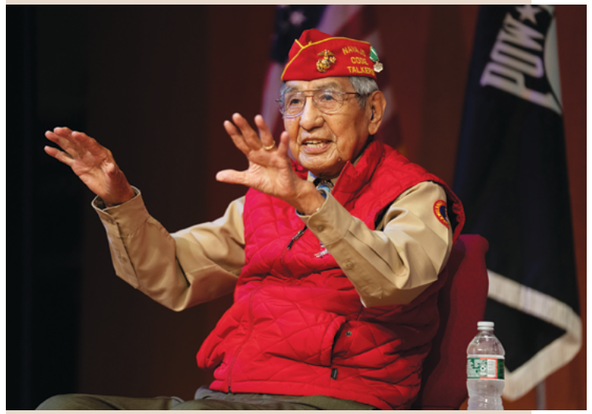
This year, the Laboratory drafted an updated Onboarding Guide to help recent hires navigate the onboarding process and their new workplace environment. The guide was created as a direct response to feedback the Laboratory received from new employees concerning additional resources that would be helpful to the newly hired. The guide joins a compendium of talent onboarding materials provided to new employees to help them acclimate to the Laboratory and connect with their colleagues.

Professional Development Week

To support new and experienced staff, the Laboratory hosted a professional development week. This series of events included a networking lunch and a panel discussion focused on advice for early-career staff. One of the seminars, "Difficult Conversations for Early-Career Professionals," explored how to respond appropriately during difficult interactions. Examples included stepping outside of one's comfort zone to initiate project requests, advocating to present a project one worked on, and applying for a promotion. The goal was for audience members to gain the confidence to engage in these types of conversations throughout their career trajectory at the Laboratory.

Discussion with Navajo Code Talker Peter MacDonald

On May 30, the Laboratory held a Memorial Day commemoration event as part of the annual Cyber Technology for National Security workshop. The Laboratory hosted a talk given by Peter MacDonald, one of the last living Navajo Code Talkers from World War II. MacDonald shared a firsthand account of how Navajo Marines used their indigenous language to create an unbreakable code, helping the U.S. military exchange secure tactical communications during the war and saving thousands of Americans and their allies. His talk gave insights into a critical chapter of American history, the accomplishments of Native American military personnel, and the vital role of cryptography in protecting national security.



Peter MacDonald talks to Laboratory employees about his experience working as a Navajo Code Talker during World War II.

EDUCATIONAL AND COMMUNITY OUTREACH 91

Laboratory volunteers guided students in the LLRISE program through the Haystack radar site in Westford, Massachusetts, to learn about the research performed there.

Educational Outreach

Middle School STEM Program

Lincoln Laboratory's Middle School STEM program offers hands-on engineering workshops for middle school students at various schools and organizations in the Boston area. This program has reached more than 300 students through 50 workshops and aims to inspire students with hands-on demonstrations and activities before they lose interest in STEM. Laboratory volunteers host workshops at the Laboratory and at Brookview House, a shelter in Dorchester, Massachusetts. Brookview strives to provide resident children with hands-on educational support while they live there.

In May, Lincoln Laboratory volunteers Yari Golden-Castano, John Hybl, Peter Asuzu, Chiamaka Agbasi-Porter, and Daphne Maldonado organized two introductory workshops for students living at Brookview House:

A Laboratory volunteer helps a student use chemical methods to identify an unknown substance during the forensics workshop.

Brookview – Intro to Forensics

The first workshop helped 20 students discover the world of forensic science. Participants spent the day learning about hair and fiber analysis, substance identification, ink and handwriting analysis, and fingerprint analysis. At the end of the workshop, the students used the skills and techniques that they had learned to solve a "crime" by comparing the evidence—handwriting samples, fabric samples, substance residue, and fingerprints—found at the scene of the crime.

Asuzu, a first-time STEM volunteer, was delighted to be a part of this effort. He said, "I think it's a wonderful opportunity to get younger students inspired about science and the scientific approach to analyzing and solving problems. The problem exercises covered a wide range of aspects that appealed to the curiosities of the students."

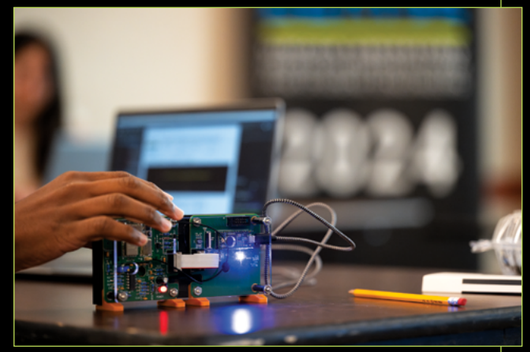
Brookview – Intro to Chemistry

The second workshop taught students about different facets of chemistry. Three experiments conducted by the Laboratory volunteers showed the difference between fluorescence, luminescence, and chemiluminescence. Students then enjoyed hands-on experiments making art by mixing powdered food coloring with citric-acid powder and baking soda. After sprinkling the powder mixture on watercolor paper, the students sprayed water on the mixture. When combined, these substances start fizzing into colored foam, creating a unique piece of art that shows the evidence of a chemical reaction. A second experiment had students add baking soda into a balloon and attach it to a bottle filled with vinegar. Participants shook the contents and saw the balloon inflate from the carbon dioxide released from the baking soda and vinegar mixture. Maldonado, who organized this effort, said, "The best part of the workshop is seeing the immediate satisfaction on the students' faces. They get to make things bubble, fizz, and pop, while simultaneously gaining a deeper understanding of the world."

John Hybl helps a budding scientist brace for what might happen when he attaches a deflated balloon onto a bottle of baking soda and vinegar and shakes it.

LINCOLN LABORATORY RADAR INTRODUCTION FOR STUDENT ENGINEERS (LLRISE)

Twenty-six students from across the country traveled to Lincoln Laboratory in July for an intensive two-week program introducing them to radar. The summer course challenges high school seniors with college-level courses in electromagnetic signal processing, radio-frequency design, pulse compression, ranging, and synthetic aperture radar. Students applied knowledge gained from the lectures as they built their own small radar systems while learning how to code in Python, use a soldering iron, and 3D print an antenna frame. After learning how to develop a good experiment, the students worked in groups to stage experiments with their radars and create a technical presentation to share their results.



A student tests a radar to detect nearby motion, which is represented on the computer as a spectrogram.

Laboratory instructors and assistants included Ryan Bohler, David Maurer, Peter Asuzu, Reginald Wilcox, David Scott, Andrew Volpe, Julian Fontes, David Brigada, Juliette Garcia-Flahaut, Alexandra Chin, Zachary Chance, John Lessard, and Allister Azagidi.

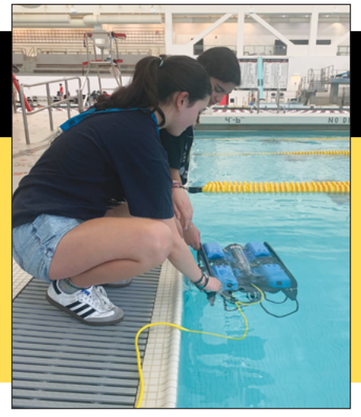
The participants enjoyed a tour of the Flight Test Facility, led by Alan Fenn and David Culbertson, and a tour of the Millstone Hill radars in Westford, Massachusetts, led by Daniel Salvucci. A career panel lunch with nine Laboratory scientists gave students the opportunity to ask questions about college, careers, life trajectories, and job expectations. Because of this program's popularity, the Laboratory also offers a shorter version, LLRISE: Spring Break, to 22 students in Massachusetts.

Allister Azagidi helps an LLRISE student understand how to use a radar and what constitutes good experimental design when developing ways to test the student-built radars.

>> Educational Outreach, cont.

Beaver Works Summer Institute (BWSI)

To rising high school seniors, BWSI offers hands-on STEM learning through project-based courses. Starting as a single class with 46 students nine years ago, BWSI has since expanded to 13 courses and 427 students in 2024, with topics spanning cybersecurity, autonomous vehicles, medical data analytics, and the application of artificial intelligence to a variety of challenging problems. The four-week program took place at the Beaver Works Center on MIT campus, featured a daily speaker from a leader in the field, and offered the following fields of study:



A student in the Autonomous Underwater Vehicles Challenge submerges her AUV to test its ability to maneuver through an underwater obstacle course.

Autonomous RACECAR (Rapid Autonomous Complex Environment Competing Ackermann-steering Robots) — Students explored the broad spectrum of research in autonomy and learned how to program a small-scale robotic system using knowledge gained in basic control systems, computer vision, sensing, perception, and elementary navigation and planning, ultimately demonstrating fast autonomous navigation in a mini grand prix.

Autonomous Underwater Vehicles (AUV) Challenge — After receiving an introduction to vehicle control, sensor integration, data analysis, image processing, and autonomy, students designed, built, and programmed an AUV to navigate an underwater obstacle course, applying real-time decision-making based on feedback from onboard sensors.

Medlytics — In Medlytics, students applied machine learning approaches to real medical problems: predicting hypothyroidism, using physiological signals to classify sleep states, and spotting cancer from mammography images. Students demonstrated a wide range of machine learning approaches, including decision trees, support vector machines, and convolutional neural networks.

Microelectronics and Hardware Development — Students were introduced to the fundamentals of hardware system design and gained skills working with circuits, transistors, and digital logic while learning how semiconductors, microchips, lasers, and solar panels work. Participants received a hardware kit to design and build their own unique electronic component.

Uncrewed Air System (UAS)–Synthetic Aperture Radar (SAR) — Participants explored radar imaging, drones, and data processing by building a fully functioning radar imaging system on a small UAS. Students learned about radar and programming in order to control a commercial radar, develop and improve radar imaging software, conduct simulated data collections, and perform data analysis.

Embedded Security and Hardware Hacking — Future security engineers learned the fundamentals of computer engineering, cryptography, system security, and cybersecurity. Student teams designed and built a secure system in an attack-and-defend-style exercise, targeting other teams' designs once their own design was completed.

Cyber Operations — This program introduced students to techniques for conducting full-spectrum cyber operations including networking,

Teams of students prepare to race autonomous racecars around an obstacle course.

Students in the Autonomous Air Vehicle Racing course test their drones.

system administration, network defense, digital forensics, and malware analysis. Participants engaged in a capstone project touching on cryptography, networking, and side channels, and the application of those technologies to nontraditional computing environments, such as industrial control systems and satellites.

Quantum Software — The course explained fundamentals of quantum information and the concepts underlying quantum computation. Students practiced with hands-on coding exercises and were challenged to implement a quantum algorithm as a software program so it could be tested, analyzed, and run.

Basics of Application-Specific Integrated Circuits — In this course on open-source semiconductor design and fabrication, students made their own semiconductor devices. Students designed devices to perform a specific function and followed the entire design process, including foundry manufacturability, after which their designs were sent to a foundry for fabrication.

Remote Sensing for Disaster Response — This emergency-management immersion course showed how to leverage open-source information and imagery collected from drones, airplanes, and satellites to generate actionable intelligence for disaster relief or humanitarian response. Students learned about remote sensing, image processing, network science, analysis techniques with artificial intelligence, and data-based decision-making.

Serious Game Design and Development with Artificial Intelligence — This course explored the use of serious games to better understand real-world situations, such as disease spread. Participants were introduced to software development, user interface design, human factors engineering, game design, and artificial intelligence, before making a modification to a game to investigate how a computer will handle moral dilemmas.

E-textiles and Wearable Tech — A new course provided students with opportunities to find applications in wearable technology, from health to fashion. After learning about textile and apparel manufacturing and electronic prototyping, students created their own piece of fully functioning wearable technology.

Autonomous Air Vehicle Racing — This new course examined the electrical, software, and aerodynamic characteristics of an autonomous platform. Students coded robotics to use computer vision, stabilize flight, avoid obstacles, and engage control theory to guide the UAV toward goals in a challenging environment.

>> *Educational Outreach, cont.*

SPOTLIGHT: Lincoln Near-Earth Asteroid Research

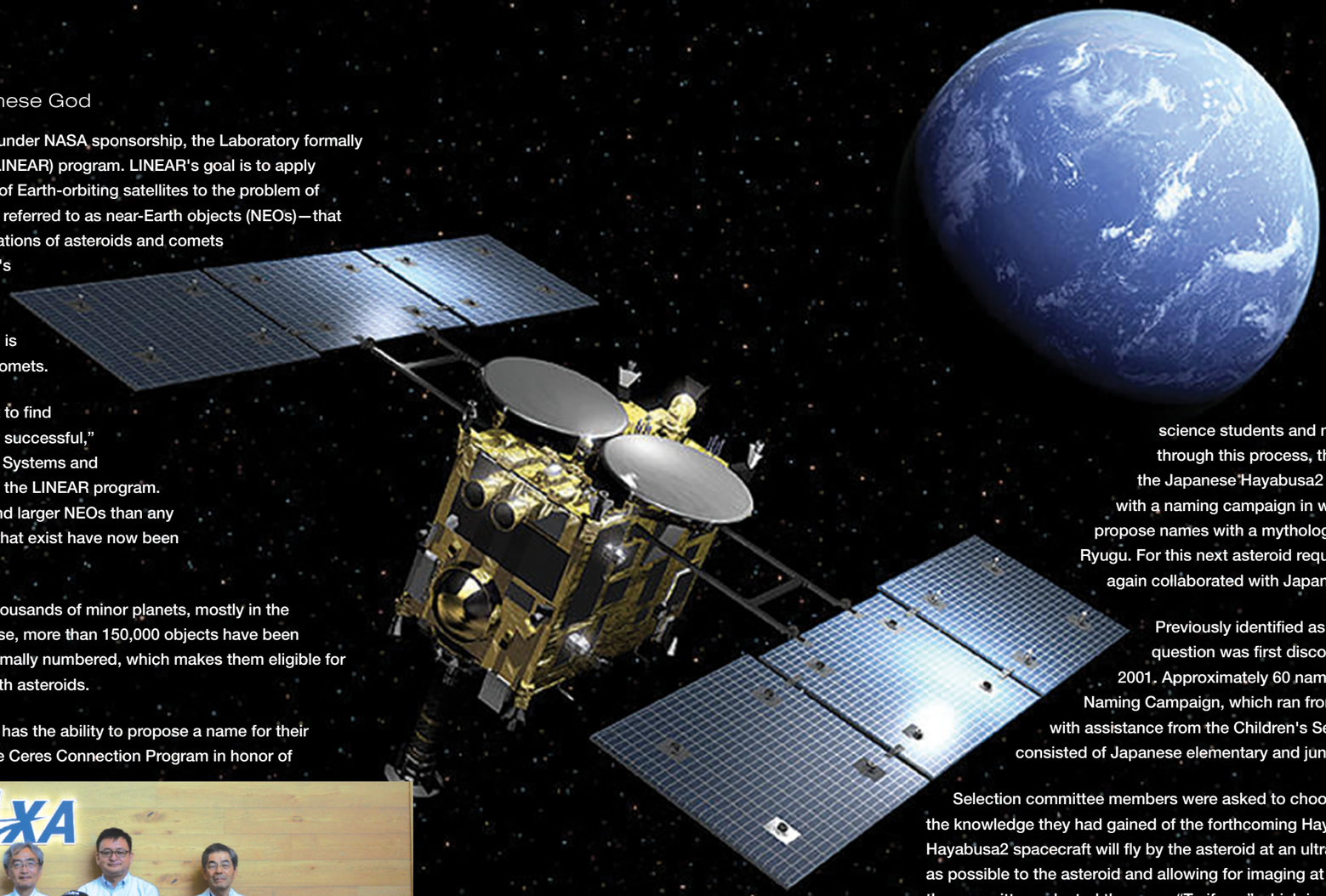
Children Name an Asteroid After Japanese God

In 1998, in collaboration with the U.S. Air Force and under NASA sponsorship, the Laboratory formally initiated the Lincoln Near-Earth Asteroid Research (LINEAR) program. LINEAR's goal is to apply technology originally developed for the surveillance of Earth-orbiting satellites to the problem of detecting and cataloging near-Earth asteroids—also referred to as near-Earth objects (NEOs)—that might threaten the Earth. All discoveries and observations of asteroids and comets are reported to the International Astronomical Union's (IAU) Minor Planet Center at the Smithsonian Astrophysical Observatory, which is responsible for verification, designation, and orbit computation, and is the official archive for all known minor planets and comets.

"As part of the Congressionally directed NASA effort to find 1-kilometer and larger NEOs, LINEAR was incredibly successful," said Grant Stokes, a Laboratory Fellow in the Space Systems and Technology Division and the principal investigator of the LINEAR program. "In fact, LINEAR has discovered more 1-kilometer and larger NEOs than any other asteroid search program. Since most of them that exist have now been discovered, that record will stand."

The LINEAR program has discovered hundreds of thousands of minor planets, mostly in the main asteroid belt between Mars and Jupiter. Of those, more than 150,000 objects have been confirmed as LINEAR discoveries by the IAU and formally numbered, which makes them eligible for naming. LINEAR has also discovered 2,680 near-Earth asteroids.

As the discoverers of these NEOs, the LINEAR team has the ability to propose a name for their discoveries, which often have been named under the Ceres Connection Program in honor of science students and mentors. For the latest asteroid to go through this process, the LINEAR team accepted a request from the Japanese Hayabusa2 Extended Mission team to collaborate with a naming campaign in which Japanese school children could propose names with a mythological origin. That asteroid was named Ryugu. For this next asteroid requiring naming, the LINEAR team once again collaborated with Japanese parties.



The Children's Selection Committee that helped name the asteroid consisted of nine elementary and junior high school students from the Young Astronauts Club of Japan and the Children, Space, Future Association. The students' acceptance to the committee was based on their application and an essay expressing their motivation.

"LINEAR has discovered more 1-kilometer and larger NEOs than any other asteroid search program."

Previously identified as (98943) 2001 CC21, the asteroid in question was first discovered by the LINEAR team on February 3, 2001. Approximately 60 names were proposed during the 2001 CC21 Naming Campaign, which ran from December 6, 2023, to May 9, 2024, with assistance from the Children's Selection Committee, whose nine members consisted of Japanese elementary and junior high school students.

Selection committee members were asked to choose the most appropriate name based on the knowledge they had gained of the forthcoming Hayabusa2 flyby mission. In July 2026, the Hayabusa2 spacecraft will fly by the asteroid at an ultrahigh speed of 5 km/s, getting as close as possible to the asteroid and allowing for imaging at high resolution. After a lively discussion, the committee selected the name "Torifune," which is a reference to the Japanese mythological god Ame-no-Torifune, who, lore states, rides upon a ship that can travel safely and steadily at high speeds. During the naming campaign, 10 people had proposed either Torifune or Ame-no-Torifune for the asteroid's name.

Following the naming campaign, the chosen name Torifune was proposed to the IAU by LINEAR team members, and after a review by the IAU, the new name was officially announced on September 23, 2024. Today, the LINEAR team consists of Laboratory staff Arthur Lue, Jenifer Evans, John Vaillancourt, Zoe Clark, Deborah Woods, Antonio Ruscitti, and Stokes. "The naming of Torifune has been a good story of international collaboration between the Laboratory, the Hayabusa2 Extended Mission team, and the elementary and junior high school students of the Children's Selection Committee," said Stokes.

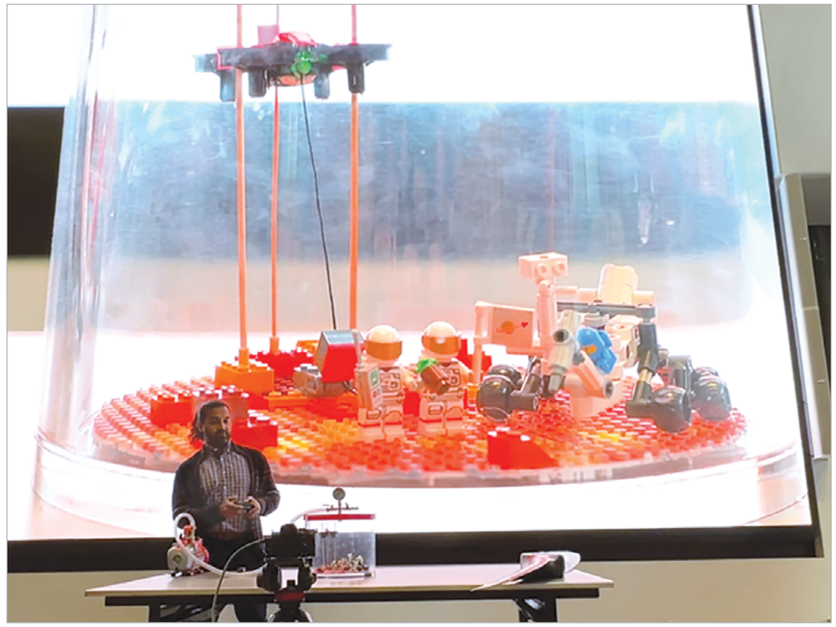
By Nathan Parde, MIT Lincoln Laboratory

>> *Educational Outreach, cont.*

MIT Museum Space Day

The MIT Museum hosts Space Day each year during Massachusetts Space Week, held during April vacation week for Massachusetts public schools. Space Week, an effort among space experts across the state, aims to make space science accessible to all. This week-long celebration fosters a shared enthusiasm for space science through engaging events such as a space film festival, a space career fair, and more than 20 space events throughout the state.

MIT Museum joins in the fun by hosting talks, demonstrations, and activities that are free with MIT Museum admission. This year's talks covered black hole echoes, moon walk navigation, and rules in outer space. Lincoln Laboratory's Thomas Sebastian and Brown University's Samuel Birch hosted a talk describing how the Ingenuity Mars Helicopter achieved powered, controlled flight on another planet for the first time in January 2024 and completed 72 flights before its mission ended. Sebastian and Birch spoke about the challenges of flying rotorcraft in conditions different than those on Earth. They explained NASA's Dragonfly mission, which aims to launch an octocopter-mounted flying laboratory to Saturn's moon in 2028. Sebastian followed with a Lego closed-dome demonstration depicting the complexities of flying on another planet with a different atmospheric pressure.



In his talk, "Flying Helicopters on Other Worlds," Thomas Sebastian used a Lego-based closed environment with adjustable pressure to show participants how a drone might fly easily in Earth's atmosphere but struggle to stay aloft in Mars's atmospheric pressure.

Astronomy at Kwajalein

As part of the educational series called Talk on the Rock, several Kwajalein staff members including Suzannah Riccardi, Jordan Montgomery, Charles Wynn, and Sarah Willis delivered the first Community Astronomy Night on Ebeye, the neighboring Marshallese community near Kwajalein. In January, the team spoke to dozens of people on Ebeye about astronomy and the great journeys that humans have taken into space. Willis summarized a variety of space missions from the past, and described upcoming launches and space science missions. The team's explanation of the new era of space exploration encouraged young participants to set out on their own journey to learn about the universe. Each talk ends with a chance to view the night skies through a telescope, and at this event, attendees were able to see the Moon, Saturn, and Jupiter. The activity sparked a lot of interest in the community because it was the first time that most of the Ebeye students had used a telescope and seen the surface of the Moon and planets.

Children of Ebeye excitedly gather around a telescope to see their first glimpse of the surface of the moon during Lincoln Laboratory's Community Astronomy Night in January.

Community Giving

Lincoln Laboratory Survivors

Sharon Tarby formed the Lincoln Laboratory Survivors Group to benefit Laboratory employees undergoing cancer treatment. With the help of volunteers, Tarby filled gift baskets with donated comfort items, such as warm fuzzy socks, books, and cocoa or tea. Tarby said, "These baskets are meant to brighten a person's day and show that we support them." A bake sale helmed by Tarby and Elizabeth Bernardo raised funds for further basket donations.

Sharon Tarby, right, delivers the first care basket from the Lincoln Laboratory Survivors Group to Caryn Cassidy.

The managers of LabAid are partnering with the Lincoln Laboratory Survivors Group, so that employees who have cancer or are caring for someone who has cancer will be offered this service as part of their care. The first gift basket was delivered to Laboratory employee Caryn Cassidy in December, an effort Tarby said was "a beautiful surprise to Caryn. It was such a heartwarming show of support to a Laboratory colleague that I hope we can continue to help many others experience a moment of joy in an otherwise difficult and challenging time." Tarby added that if there are people in the Laboratory community who might be eligible to receive a care basket, they should contact Lincoln Laboratory Survivors or LabAid.

Gaining Ground Farm

Two work sessions were held this year at Gaining Ground Farm, a nonprofit organic farm in Concord, Massachusetts. Thousands of community volunteers work at the farm, which donates its food to 17 area meal programs and food pantries. Joan Boegel, who organized both days, said "We accomplished a lot in a couple of hours and got plenty of sunshine."

In June, 12 gardeners from Lincoln Laboratory helped prepare a field for butternut squash by weeding and spreading compost. In September, 13 Lincoln Laboratory employees volunteered. The group will continue helping Gaining Ground Farm in its mission to donate organic produce for hunger relief.

Laboratory volunteers help Gaining Ground Farm spread compost on a field and clear a cabbage field.

Greater Boston Food Bank

Members of the Lincoln Laboratory community played a crucial role in February in helping address hunger in Eastern Massachusetts. Chiamaka Agbasi-Porter, William Gibbs, and Spencer Johnson organized a volunteer day to help the largest hunger-relief organization in New England, the Greater Boston Food Bank (GBFB) in Boston, Massachusetts. Through support from its partners and volunteers, GBFB distributes food to community meal programs and local food pantries. GBFB relies on volunteers to help sort and pack donated food items, and ensure that they are properly organized and ready for distribution. Eleven Laboratory volunteers at GBFB helped pack boxes of food for distribution to needy families and individuals in the greater Boston area.

Eleven volunteers at GBFB helped pack boxes of food for distribution to needy families and individuals in the greater Boston area.

GOVERNANCE AND ORGANIZATION

MIT Lincoln Laboratory

Laboratory Governance and Organization

MIT
Sally A. Kornbluth
President

Cynthia Barnhart
Provost

Ian A. Waitz
Vice President for Research

2024 DoD Joint Advisory Committee

The committee annually reviews the Laboratory's proposal for programs to be undertaken in the subsequent fiscal year and five-year plan.

Aprille J. Ericsson, Chair
Assistant Secretary of Defense for Science and Technology

The Honorable Douglas R. Bush
Assistant Secretary of the Army for Acquisition, Logistics & Technology

Brigadier General Scott A. Cain
Commander, Air Force Research Laboratory

Lieutenant General Heath A. Collins
Director, Missile Defense Agency

The Honorable Andrew P. Hunter
Assistant Secretary of the Air Force (Acquisition, Technology and Logistics)

Christopher Scolese
Director, National Reconnaissance Office

Frederick J. Stefany
PTDO Assistant Secretary of the Navy for Research, Development and Acquisition

Stefanie Tompkins
Director, DARPA

Dennis L. D'Angelo
Executive Director
Air Force Life Cycle Management Center

2024 Lincoln Laboratory Organization

Melissa G. Choi
Director

Justin J. Brooke
Assistant Director

C. Scott Anderson
Assistant Director – Operations

Israel Soibelman
Chief Strategy Officer

Heidi C. Perry
Chief Technology Officer

Asha Rajagopal
Chief Technology Ventures Officer

Chevalier P. Cleaves
Chief Diversity and Inclusion Officer

Robert D. Loynd
Executive Officer and Chief of Staff

Office of the Director

David Suski
Ethics and Compliance Assurance Office

Brian O. Primeau
Environmental Health and Safety

J. Michael Menadue
Capital Projects

Daniel M. Marcus
Mission Assurance

Jacob M. Williams
Program Management

Dennis A. Burianek
Business Transformation

David Culbertson
Flight Test Facility

David R. Granchelli
Communications and Community Outreach

Operations Departments

Donald L. Vandeveer
Contracting Services

Joseph Dolan
Facility Services

John M. Adams
Financial Services

Kerry A. Harrison
Human Resources

Robert D. Solis
Information Services

Derek W. Jones
Chief Security Officer

Advanced Technology

Robert G. Atkins
Head

Livia M. Racz
Associate Head

Mark A. Gouker
Assistant Head

Air, Missile, and Maritime Defense Technology

Katherine A. Rink
Head

Aryeh Feder
Assistant Head

Mabel D. Ramirez
Assistant Head

Sung-Hyun Son
Assistant Head

Biotechnology and Human Systems

Edward C. Wack
Head

Jeffrey S. Palmer
Assistant Head

Christina M. Rudzinski
Assistant Head

Communication Systems

Thomas G. Macdonald
Head

James Ward
Associate Head

Michele A. Schuman
Assistant Head

Cyber Security and Information Sciences

Stephen B. Rejto
Head

Marc A. Zissman
Associate Head

Jeffrey C. Gottschalk
Assistant Head

Engineering

Edwin F. David
Head

Keith B. Doyle
Assistant Head

Kristin N. Lorenze
Assistant Head

Homeland Protection and Air Traffic Control

Jennifer A. Watson
Head

James K. Kuchar
Assistant Head

Jonathan D. Pitts
Assistant Head

Christopher A.D. Roeser
Assistant Head

Intelligence, Surveillance, and Reconnaissance and Tactical Systems

Marc N. Viera
Head

M. Jalal Khan
Assistant Head

Daniel J. Ripin
Assistant Head

Scott Van Broekhoven
Assistant Head

Space Systems and Technology

D. Marshall Brenizer
Head

Gregory D. Berthiaume
Assistant Head

Pamela R. Evans
Assistant Head

Timothy D. Hall
Assistant Head

Pablo I. Hopman
Assistant Head

2024 MIT Lincoln Laboratory Advisory Board

The Advisory Board is appointed by the MIT President and reports to the Provost. The board meets twice a year to review the direction of Laboratory programs.

Kent Kresa, Chairman
Former Chairman and CEO, Northrop Grumman

ADM Edmund P. Giambastiani Jr., USN (Ret)
Former Vice Chairman of the Joint Chiefs of Staff

Paul G. Kaminski
Chairman and CEO, Technovation, Inc.; Former Under Secretary of Defense for Acquisition and Technology

Denis A. Bovin
Senior Advisor, Evercore Partners; Life Member, MIT Corporation; Former Member, President's Foreign Intelligence Advisory Board

Daniel E. Hastings
Aeronautics and Astronautics Department Head, MIT

The Honorable Ellen M. Lord
Former Under Secretary of Defense for Acquisition and Sustainment, President and CEO, Textron Systems Corporation

Arup K. Chakraborty
Institute Professor, MIT, Professor of Chemical Engineering, Physics, and Chemistry

Deborah Lee James
Board of Directors, Textron and Unisys; Former Secretary of the Air Force

Gen Lester L. Lyles, USAF (Ret)
Board of Directors, General Dynamics Corporation; Former Vice Chief of Staff of the Air Force; Former Commander, Air Force Materiel Command

Mark R. Epstein
Senior Vice President for Development, Qualcomm Incorporated; Life Member Emeritus, MIT Corporation

Miriam E. John
Vice President Emeritus, Sandia National Laboratories

John P. Stenbit
Former Assistant Secretary of Defense (C3I); Former Executive Vice President, TRW

VADM David E. Frost, USN (Ret)
President, Frost & Associates, Inc.; Former Deputy Commander, U.S. Space Command

Anita K. Jones
Professor Emerita, University of Virginia; Former Director of Defense Research and Engineering

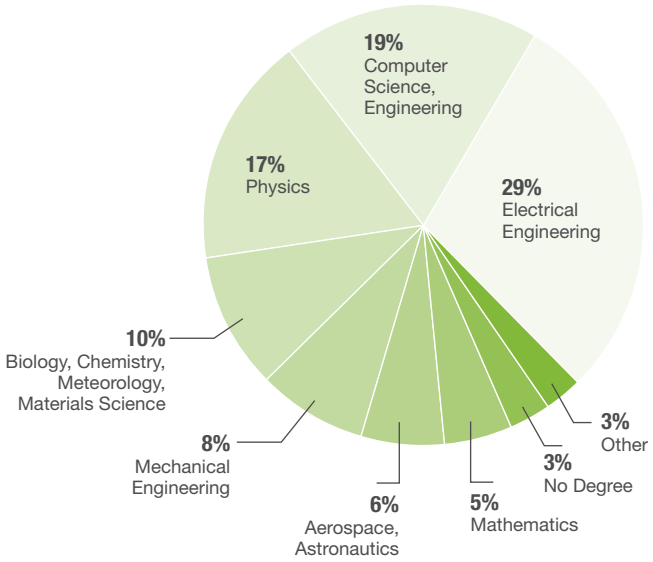
Ian A. Waitz
Vice President for Research, MIT; Jerome C. Hunsaker Professor of Aeronautics and Astronautics, MIT

Staff and Laboratory Programs

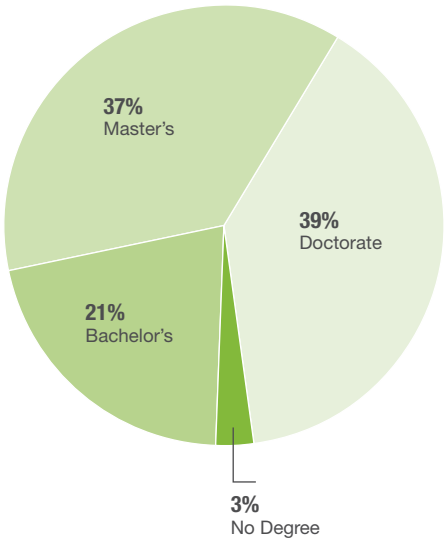
2,124	Professional Technical Staff
1,452	Support Personnel
536	Technical Support Personnel
429	Subcontractors
4,541	**Total Employees**

Composition of Professional Technical Staff

Academic Discipline

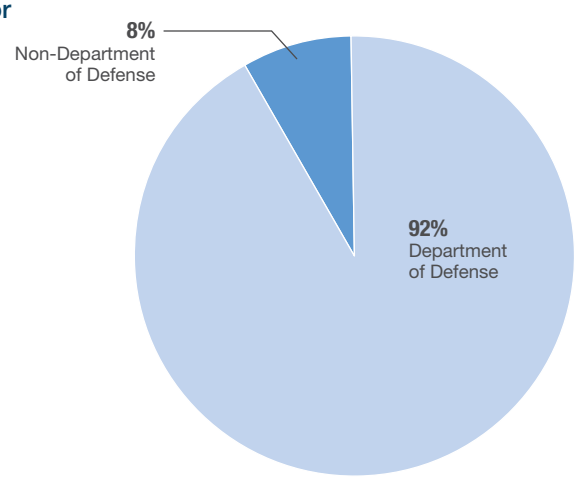


Academic Degree

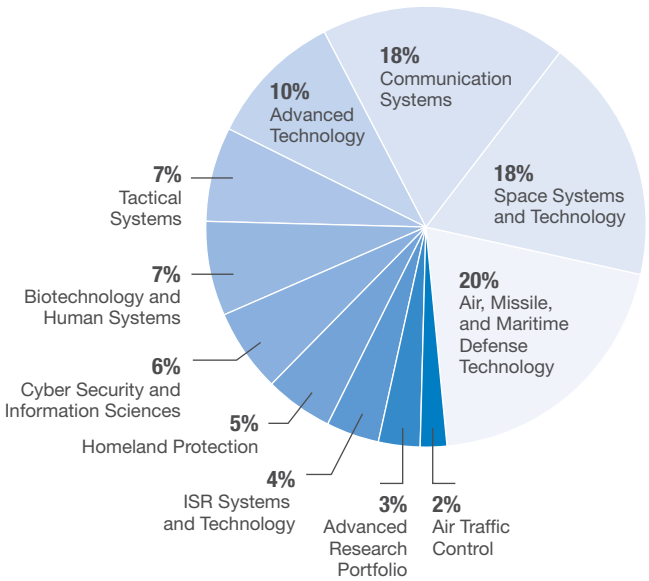


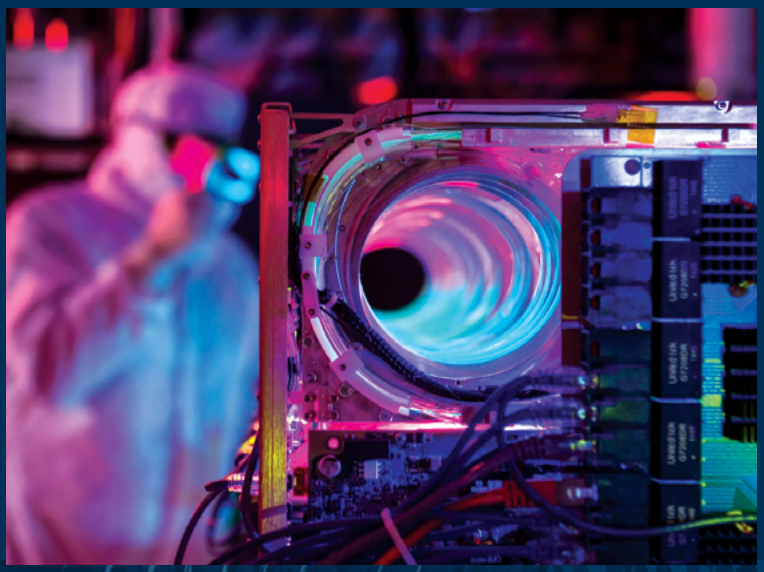
Breakdown of Laboratory Program Funding

Sponsor



Mission Area





LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
244 Wood Street ▪ Lexington, Massachusetts 02421-6426

Approved for public release: distribution unlimited. This material is based upon work supported by the Department of the Air Force under Air Force Contract No. FA8702-15-D-0001. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of the U.S. Air Force.

TECHNOLOGY IN SUPPORT OF NATIONAL SECURITY

Follow MIT Lincoln Laboratory online

: MIT Lincoln Laboratory

: @lincoln_laboratory

: MIT Lincoln Laboratory

: @MITLL

: MIT Lincoln Laboratory

: @lincoln_laboratory

WWW.LL.MIT.EDU

Communications and
Community Outreach Office
781.981.4204