Section 5
Lincoln Laboratory

Lincoln Laboratory

MIT Lincoln Laboratory is a federally funded research and development center (FFRDC) operated by the Institute under contract with the Department of Defense (DoD). The Laboratory's core competencies are in sensors, information extraction (signal processing and embedded computing), communications, integrated sensing, and decision support, all supported by a strong program in advanced electronics technology.

Lincoln Laboratory's mission is to apply technology to problems of national security. Technology development is focused on these research areas—space control; air, missile, and maritime defense technology; communication systems; cyber security and information sciences; intelligence, surveillance, and reconnaissance systems; advanced technologies; artificial intelligence; bioengineering and biomedical research; autonomous systems; microelectronics; quantum systems; energy; tactical systems; and homeland protection; as well as nondefense projects in air traffic control and weather surveillance.

Two of our principal objectives are (1) development of components and systems for experiments, engineering measurements, and tests under field operating conditions and (2) dissemination of information to the government, academia, and industry. Program activities extend from fundamental investigations through the design process, to field demonstrations of prototype systems. Emphasis is placed on transitioning systems and technology to operational use in military deployments and to the defense industry.

MIT Lincoln Laboratory also maintains long-term competency, retains high-quality staff, provides independent perspective on critical issues, sustains strategic sponsor relationships, and develops technology for long-term interests and short-term, high-priority needs of our DoD sponsors. Significant milestones reached in several areas represent only a fraction of the technology developed over the past year.

- A novel infrared search-and-track system that was tested in maritime environments will be used to inform the design of a future naval sensor for persistent surveillance.
- The Laboratory's advanced imaging ladar system was flown over Puerto Rico to generate a baseline map of ground conditions that will be used to direct U.S. recovery efforts if a disastrous hurricane hits again.
- The Micro-sized Microwave Atmospheric Satellite CubeSat, launched into low Earth orbit in early 2018, successfully demonstrated an advanced compact microwave sounder and provided the first multiband radiometer measurements from a CubeSat payload.
- A NASA probe called the Transiting Exoplanet Survey Satellite (TESS) was launched into orbit last spring. This probe, developed with the MIT Kavli Institute for Astrophysics and Space Research, and NASA's Goddard Space Flight Center, will search for Earth-like planets that may have the possibility of harboring life.
- Through our R&D into technology to protect the nation's critical infrastructure, such as mass transit systems, against explosive attacks, we demonstrated a system to detect threats concealed on persons who are in areas of high pedestrian traffic.
- A new field-programmable imaging array integrated circuit that can be reused by multiple ladar and imaging systems greatly extends the capabilities of the widely adaptable digital focal plane array we developed.
- We successfully demonstrated the first balloon-based communications relay array, which used ten balloon-borne payloads to achieve over-the-horizon communications despite co-channel interference.
- Our energy resilience analysis methodology and software were deployed to 27 Department of Defense installations around the world and are slated to be adopted by more military installations for future energy assessments.
- We have developed architectures that allow us to integrate cyber security into small satellites.

Lincoln Laboratory—Past and Future

The Founding of MIT Lincoln Laboratory

In September 1949, President Truman announced that the rumors of a Soviet nuclear capability were well founded; the world had evidence that an atomic bomb had been tested by the Soviets in August. This news and the subsequent confirmation that the Soviet Union had developed long-range aircraft capable of reaching the United States via an Arctic route caused the Department of Defense to examine its defenses against an air attack. When the DoD determined that the nation did not have an effective, modern system that would provide timely warning of, and then engage countermeasures to, a nuclear air strike, it tasked the Air Force with improving U.S. air defenses.

A committee led by the Air Force and made up of experts in aeronautics, physics, and radar studied the problem and proposed the creation of a laboratory to develop a new air defense system. Because of the seminal, and revolutionary, work on radar systems done at MIT's Radiation Laboratory to support the Allies' efforts during World War II, this Air Defense Systems Engineering Committee proposed the laboratory be run by MIT.

The Lincoln Laboratory Site at Hanscom AFB

MIT President James Killian initially was not eager to engage the Institute in another long-term, complex, and classified military project, preferring to see MIT resources return to the mission of education and open research. However, he finally agreed to this new venture, but with the stipulation that the laboratory be located away from the MIT campus, which he wished to maintain as a research environment unencumbered by security restrictions.

The Air Force, which was the sponsor for the new air defense system, already owned the Hanscom AFB site. It had ample space for a new facility and access to Air Force consultants. So in 1951, construction began on the buildings that would be the home of R&D into the radar-based air defense system called SAGE (for Semi-Automatic Ground Environment). For the next six years, Lincoln Laboratory developed the SAGE system, which eventually digitally connected 100s of radars to an array of command centers, transformed computing by pioneering the magnetic core memory, and spawned several defense companies.

Lincoln Laboratory as an FFRDC

Lincoln Laboratory was founded as a federally funded research and development center (FFRDC). An FFRDC assists the U.S. government with scientific research and analysis, systems development, and systems acquisition to provide novel, cost-effective solutions to complex government problems. Combining the expertise and outlook of government, industry, and academia, FFRDCs are independent, nonprofit labs that are prohibited from competing with industry or working for commercial companies.

Each FFRDC is sponsored by a government agency but is privately managed by a university or another not-for-profit organization. Currently, 42 FFRDCs are providing various U.S. government agencies with R&D in fields ranging from defense to energy, space, and health and human services. Lincoln Laboratory is a Department of Defense FFRDC, managed by MIT under a contract with the U.S. Air Force.

Lincoln Laboratory's Move to the Future

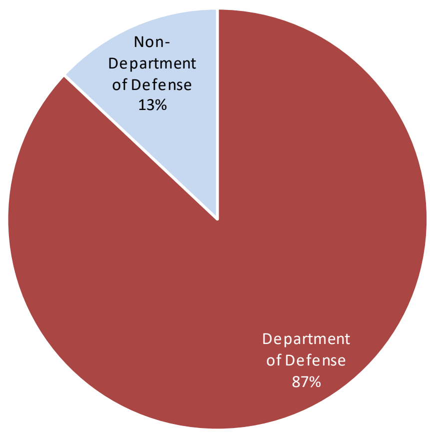
After the SAGE system was completed, Lincoln Laboratory—with its technological experience, excellent technical staff, and lab and computing facilities—was positioned to tackle new DoD problems, a chief one being the advent of ballistic missiles. For 68 years, Lincoln Laboratory has found new challenges to undertake, applying its deep and broad knowledge of sensors and signal processing to developing technology for not only air and missile defense but also communication systems, space systems, advanced imaging, and more recently bioengineering, cybersecurity, and artificial intelligence.

To support the wide variety of its work that requires advanced microelectronics, Lincoln Laboratory is undertaking the construction of a Compound Semiconductor Laboratory and Microsystem Integration Facility. The new facility will be part of the research complex that still contains the four original 1951-era buildings, the Microelectronics Laboratory built in the early 1990s, and South Laboratory completed in 1995.

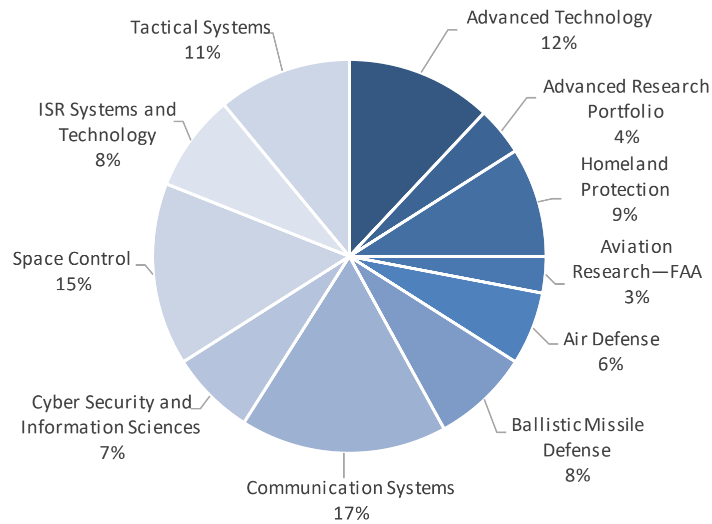
Breakdown of Laboratory Program Funding

Total Funding FY2018*= $1,027.1 million

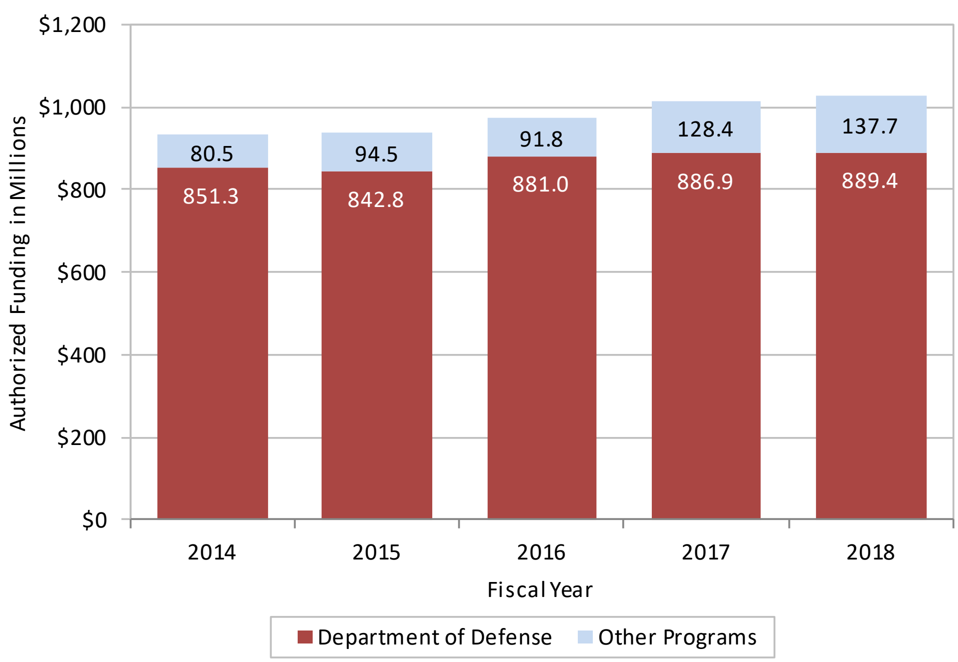
Sponsor



Mission Area



Total Funding
Fiscal Years 2014–2018*



*Lincoln Laboratory fiscal year runs concurrent with the U.S. Government fiscal year, October 1–September 30.

Major Programs/Prototypes

Early Alerts to Pathogen Exposure

Researchers at Lincoln Laboratory, in collaboration with the National Institutes of Health Integrated Research Facility (NIH-IRF) and the U.S. Army Medical Research Institute of Infectious Diseases (USAMRIID), developed the Presymptomatic Agent Exposure Detection (PRESAGED) algorithm that provides early identification of pathogen exposures. The algorithm uses real-time physiological data, such as heart rate or core body temperature, to calculate the probability of a person's having been exposed to a virus or bacteria. A Laboratory team evaluated outbreak responses ranging from isolation of individuals with overt symptoms to broad quarantine of people with a probability of pathogen exposure. Through simulation and modeling, they estimated the spread of infection under different quarantine responses, and they calculated the effects of PRESAGED early warning on those estimates. Initial results show that the spread of infection could be almost halved if PRESAGED prompted early treatment and isolation of individuals identified as having been exposed to the pathogen.

TESS Cameras Will Discover Exoplanets

The Transiting Exoplanet Survey Satellite (TESS) is a NASA Astrophysics Explorer mission led and operated by MIT and managed by NASA's Goddard Space Flight Center. Aboard TESS are four identical cameras that Lincoln Laboratory developed in collaboration with the MIT Kavli Institute for Astrophysics and Space Research. Over a two-year mission, these cameras will gaze at 85% of the sky, collecting photons given off from 20 million neighboring stars and capturing any discreet dips in these stars' brightness. These dips in light indicate that an exoplanet—a planet outside of our solar system—is orbiting the star. To record the intensity and position of light, charge-coupled devices (CCDs) convert photons into electrons that are then stored in a pixel. Laboratory engineers achieved very high photon sensitivity in the CCDs, which allows the CCD to collect more light at the pixel level. Scientists expect TESS to discover thousands of new exoplanets. Through its observations, TESS will build a catalog of exoplanets that are close enough to our solar system to be studied in greater detail with ground-based telescopes.

Ladar Helps Assess Damage in Puerto Rico

In the wake of a disaster, responding agencies need to assess damage quickly to determine where to focus their efforts. Conducting damage assessments is currently a slow, manual process that requires Federal Emergency Management Agency (FEMA) personnel to walk, drive, and fly around to document and inspect damage. Lincoln Laboratory is using ladar and specialized algorithms to help FEMA automate damage assessments and speed up recovery actions.

During summer 2018, researchers scanned the entire island of Puerto Rico with the Airborne Optical Systems Testbed (AOSTB). The AOSTB uses single-photon-sensitive, time-of-flight imaging technology to collect information about the surface characteristics of the land below. This ladar system, which is 10 to 100 times more capable than any commercial system available, enabled staff to generate a high-resolution 3D ladar map of the island that showed the latest topographical conditions and debris resulting from the 2017 hurricanes.

Laboratory staff developed automated algorithms to quickly find points of interests on the map, such as buildings, roads, and powerlines. FEMA used this information to assess damages, quantify debris, inspect infrastructure, and monitor erosion and reconstruction. The data were also used for preventative purposes, for example, to model flood plains in areas where new infrastructure is being planned. Lincoln Laboratory plans to expand this work by adding additional sensors to the AOSTB and collecting data over other areas of the United States that are susceptible to natural disasters.

Major Technology Transfers

Air, Missile, and Maritime Defense Technology

Lincoln Laboratory prototyped and demonstrated automation algorithms and associated operator displays in support of wide-area passive acoustic undersea surveillance. The intellectual property was transitioned to PMS-485 and is undergoing further development to be inserted into the Integrated Undersea Surveillance System common software suite.

Air Traffic Control

Air traffic controllers in Houston, Miami, San Juan, and New York, and at the National Air Traffic Control System Command Center near Washington, D.C., are using radar-like images estimated by the Offshore Precipitation Capability that was developed by Lincoln Laboratory to help plan safe, efficient routes through airspace over oceanic regions outside the coverage of land-based radar systems.

Supercomputing

The BigDAWG polystore system, created with MIT and other universities, was released as an open-source product. Polystore systems have spurred a new field of database research, and BigDAWG as a software package is currently being evaluated by a number of organizations.

The GraphBLAS open standard that was created by a consortium led by the research team at the Lincoln Laboratory Supercomputing Center to solve large graph problems was officially released to the community. The Julia programming language, co-founded by the Lincoln Laboratory Supercomputing Center and used by millions of programmers worldwide, was successfully transitioned to a startup company.

Communication Systems

The design for a compact off-axis telescope was transitioned to industry in support of laser communication terminals being developed for NASA's Orion Crew Exploration Vehicle and the International Space Station.

Cyber Security and Information Sciences

Software developed in a project called the Scalable Cyber Analytic Processing Environment was released as open-source. The software allows researchers to explore multisource cyber defense datasets. We transferred a Security Cyber Module prototype to be used for securing communication of future ground unmanned systems, such as explosive-ordnance disposal robots. The Laboratory also transferred its high-assurance cryptographic and key management technology, called SHAMROCK, to GE Aviation in support of the Agile Resilient Embedded Systems program. In support of the U.S. Army's High Performance Computing Modernization Program, the Cyber Adversarial Scenario Modeling and Artificial Intelligence Decision Engine prototype is being transitioned to provide automated network segmentation in response to detected cyber threats.

Open-Source Analytics and Tools

Lincoln Laboratory transitioned 10 state-of-the-art open-source analytics and tools to the Defense Advanced Research Projects Agency's Memex Open Catalog:

- MIT Information Extraction Toolkit
- Lincoln Laboratory Text Classification tool
- Topic classifier
- Speech processing tool for speaker, language, and gender recognition
- VizLinc, a visual analytics platform
- TweetE, a tool for processing Twitter postings
- Lincoln Laboratory Author Classification tool
- String processing software
- Tool for efficient searching via an index of locality-sensitive hash tags
- GraphQuBE, a tool that enables graph query-by-example

Lincoln Laboratory Mission Areas

Air, Missile, and Maritime Defense Technology
Researchers in this area are investigating system architectures, prototyping pathfinder systems, and demonstrating these advanced, integrated sensor systems that are designed for use on tactical air and maritime platforms to provide defense against missiles and other threats.

Communication Systems
The work in this research area focuses on developing and demonstrating tactical network radios, radio-frequency (RF) military satellite communications, free-space laser communications, and quantum systems to expand and protect the nation's global defense networks.

Cyber Security and Information Sciences
Goals in this research area include 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.

Intelligence, Surveillance, and Reconnaissance Systems and Technology
We are 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.

Tactical Systems
Tactical Systems researchers improve the development of tactical air and counterterrorism systems through systems analysis to assess the impact of technologies on real-world scenarios; rapidly develop prototype systems; and conduct precise instrumented testing of systems.

Space Control
Lincoln Laboratory's scientists are ensuring the resilience of the nation's Space Enterprise by designing, prototyping, operating, and assessing systems to provide space situational awareness, resilient space capability delivery, active defense, and associated cross-domain battle management.

Advanced Technology
In the Advanced Technology research area, we are Leveraging solid-state electronic and electro-optical technologies, chemistry, materials science, advanced RF technology, and quantum information science to develop innovative system applications and components.

Homeland Protection
The Homeland Protection mission area creates innovative technology and architectures to help prevent terrorist attacks within the United States, to reduce the vulnerability of the nation to terrorism, to minimize the damage from terrorist attacks, and to facilitate recovery from man-made and natural disasters.

Air Traffic Control
At Lincoln Laboratory, aviation researchers are developing advanced technologies and decision support architectures for aircraft surveillance, integrated weather sensing and processing, collaborative air traffic management, and information security to support the nation's air transportation system.

Advanced Research Portfolio
The internal research and development at Lincoln Laboratory is supported through congressionally appropriated funding, known as the Line. The Line is the primary source of relatively unconstrained funding and is used to fund the long-term strategic technology capabilities of established and emerging mission areas. Line projects form an Advanced Research portfolio focused on addressing technology gaps in critical problems facing national security.

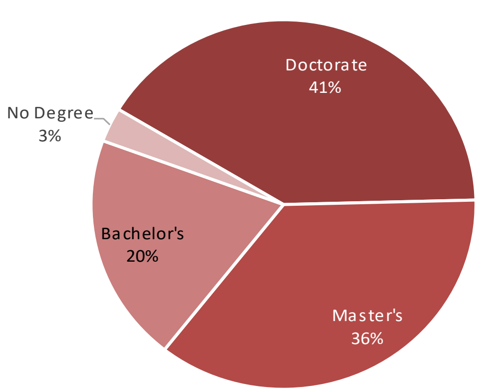
Lincoln Laboratory Technical Staff

Lincoln Laboratory employs 1,772 technical staff, 574 technical support personnel, 1,068 support personnel, and 461 subcontractors. Three-quarters of the technical staff have advanced degrees, with 41% holding doctorates. Professional development opportunities and challenging cross-disciplinary projects are responsible for the Laboratory's ability to retain highly qualified, creative staff. As employees of MIT, staff contribute in many ways to the MIT community.

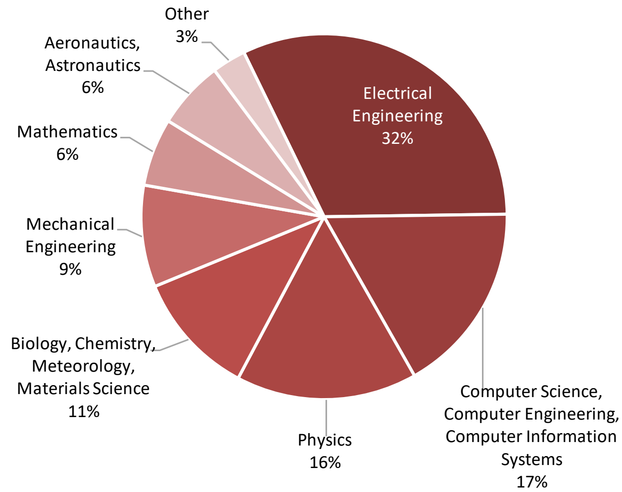
Our status as a large multidisciplinary research and development center makes it a strong resource for collaborative research initiatives. Several ongoing programs connect staff at the Laboratory with researchers, faculty, and students at MIT. These initiatives focus on researching new technology, challenging students to solve interesting problems, and engaging Laboratory staff in teaching new skills. The synergy between the campus's focus on academic research and the Laboratory's experience in building prototypes has resulted in the development of innovative systems.

Lincoln Laboratory recruits at many of the nation's top technical universities, with 65 to 75% of new hires coming directly from universities. Lincoln Laboratory augments its campus recruiting by developing long-term relationships with research faculty and promoting fellowship and summer internship programs.

Academic Degrees Held by Staff



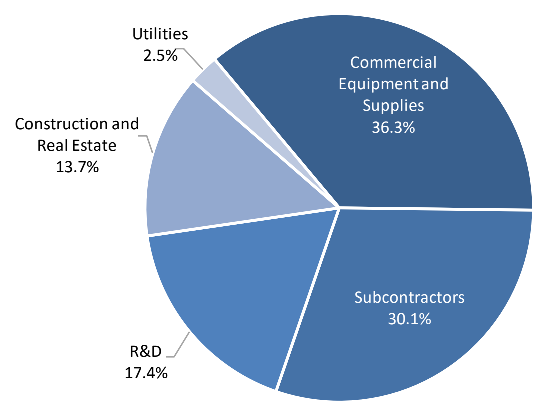
Academic Disciplines of Staff



Lincoln Laboratory's Economic Impact

During fiscal year 2018, the Laboratory issued subcontracts with a value of approximately $437 million. The Laboratory awarded subcontracts to businesses in all 50 states. Massachusetts businesses were awarded $194 million in contracts, and states as distant as Colorado and California also realized significant benefits to their economies.

Contracted Services (FY2018)*



*Estimates from $436.9M, total FY2018 spend.

- Includes orders to MIT ($10.3M)
- Figures are net awards less reductions

MIT/Lincoln Laboratory Interactions

Lincoln Laboratory invests in developing and sharing the knowledge that will drive future technological advances and inform the next generation of engineers. Our educational collaborations with MIT are below.

Independent Activities Period at MIT

Lincoln Laboratory technical staff led activities offered during MIT's Independent Activity Period (IAP) in 2018. Lincoln Laboratory offered eight noncredit courses organized and led by its technical staff members. Many of this year's IAP noncredit activities were held at Beaver Works on the MIT campus.

VI-A Master of Engineering Thesis Program

Students in MIT's VI-A Master of Engineering Thesis Program spend two summers as paid interns at Lincoln Laboratory, contributing in projects related to their courses of study. Then, the students work as research assistants while developing their master of engineering theses under the supervision of both Laboratory engineers and MIT faculty. Typically, about a half-dozen students participate in the program, gaining experience in testing, design, development, research, and programming.

Research Assistantships

Lincoln Laboratory employs a limited number of research assistants from MIT. Working with engineers and scientists for three to five years, these students contribute to sponsored programs while investigating the questions that evolve into their doctoral theses.

Undergraduate Research Opportunities and Practice Opportunities Programs

Lincoln Laboratory partners with MIT's Undergraduate Research Opportunities Program (UROP) and Undergraduate Practice Opportunities Program (UPOP). Program participants at the Laboratory develop research proposals, perform experiments, and analyze data. In summer 2018, 20 undergraduates were hired as UROP interns and six as UPOP interns.

Advanced Concepts Committee

The Advanced Concepts Committee (ACC) provides funding and technical support for researchers who are investigating novel concepts that address high-priority national problems. The ACC encourages collaborative projects with MIT faculty and funds projects conducted by MIT researchers in areas pertinent to Laboratory programs.

Beaver Works

Beaver Works, a joint initiative between Lincoln Laboratory and the MIT School of Engineering, serves as a mechanism for expanding project-based learning opportunities for students. By leveraging expertise of Lincoln Laboratory staff, MIT faculty, researchers, Beaver Works is strengthening research and educational partnerships to find solutions to pressing global problems.

The signature Beaver Works collaboration is the capstone course, an MIT engineering class which involves a project to develop technology that solves a real-world problem. The fabrication areas offer access to high-tech equipment, such as 3D printers and a laser cutter, that support construction of prototypes by students from the engineering department, the MIT Robotics Club, and the MIT UAV Club. At Beaver Works, MIT undergraduate and graduate students participated in the Assistive Technologies Hackathon (ATHack), in which students prototyped engineering solutions to problems faced by the disabled.

Beaver Works extends project-based learning to K–12 schoolchildren. In 2018, eight groups were involved in programs held at the center, including a build-a-radar workshop directed by Lincoln Laboratory instructors; weekly practices for CyberPatriot teams that participate in computer-network security challenges; and the Beaver Works Summer Institute--a summer camp program that offers hands-on engineering challenges for high school students.

Beaver Works recently opened a 4,000-sq-ft auxiliary space that will facilitate collaboration between MIT Aero/Astro and Lincoln Laboratory.

Test Facilities and Field Sites

Hanscom Field Flight and Antenna Test Facility. The Laboratory operates the main hangar on the Hanscom Air Force Base flight line. This 93,000-sq-ft building accommodates the Laboratory Flight Test Facility and a complex of state-of-the-art antenna test chambers. The Flight Test Facility houses several Lincoln Laboratory–operated aircraft used for rapid prototyping of airborne sensors and communication.

Hanscom Field Flight and Antenna Test Facility

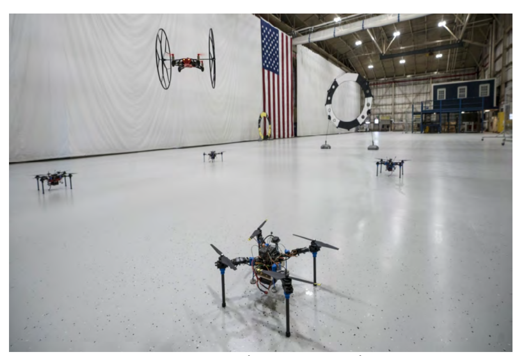
Millstone Hill Field Site, Westford, MA
MIT operates radio astronomy and atmospheric research facilities at Millstone Hill, an MIT-owned, 1,100-acre research facility in Westford, Massachusetts. Lincoln Laboratory occupies a subset of the facilities whose primary activities involve tracking and identification of space objects.

Millstone Hill Field Site, Westford, Massachusetts

Reagan Test Site, Kwajalein, Marshall Islands
Lincoln Laboratory serves as the scientific advisor to the Reagan Test Site at the U.S. Army Kwajalein Atoll installation located about 2,500 miles WSW of Hawaii. Twenty staff members work at this site, serving two- to three-year tours of duty. The site's radars and optical and telemetry sensors support ballistic missile defense testing and space surveillance. The radar systems provide test facilities for radar technology development and for the development of ballistic missile defense techniques.

Reagan Test Site, Kwajalein, Marshall Islands

Autonomous Systems Development Facility
This new state-of-the-art facility located on Hanscom Air Force Base enables the development and testing of ground-based, aerial, and undersea autonomous systems. Infrared sensors and a motion caption system localizes reflective tags on vehicles, relaying position and orientation data in real time.



Autonomous Systems Development Facility

Lincoln Laboratory Outreach Metrics

Community outreach programs are an important component of the Laboratory's mission. Outreach initiatives are inspired by employees' desire to help people and to motivate student interest in science, technology, engineering, and mathematics (STEM). Some samples of our programs are listed below.

LLRISE

Eleven technical staff members taught various portions of the Lincoln Laboratory Radar Introduction for Student Engineers (LLRISE) Workshop and helped high-school students build their own Doppler and range radars. The students were instructed in 3D printing, circuit board assembly, electromagnetics, pulse compression, signal processing, antennas, MATLAB, and electronics. The program expanded to include two high school physics teachers in hopes that they may learn how to integrate the workshop in their own after-school curriculum. The program also offered a one-day workshop for eighth- to twelfth-graders to provide a sample of the workshop.

LLCipher

LLCipher introduces high-school students to modern cryptography—a math-based, theoretical approach to securing data. Abstract algebra, number theory, and complexity theory provide the foundational knowledge needed to understand theoretical cryptography.

Explorer Post 1776

Lincoln Laboratory sponsors a co-ed Explorer Post through the Boy Scouts of America so that high school students can build engineering systems, design prototypes, and use creative problem-solving skills.

Beaver Works Summer Institute

This program for high school students from across the country offers hands-on STEM challenges in several different areas: programming for autonomous cognitive assistants, robotics, or autonomous air vehicles; 3D printing, data science for health medicine, building a CubeSat, and unmanned air system.