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.

Since its establishment in 1951, MIT Lincoln Laboratory's mission has been to apply technology to problems of national security. The Laboratory's technology development is focused on its primary mission areas—space control; air and missile defense technology; communication systems; cyber security and information sciences; intelligence, surveillance, and reconnaissance systems and technology; advanced technologies; tactical systems; and homeland protection. In addition, Lincoln Laboratory undertakes government-sponsored, nondefense projects in areas such as air traffic control and weather surveillance.

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

MIT Lincoln Laboratory also emphasizes meeting the government's FFRDC goals of maintaining long-term competency, retaining high-quality staff, providing independent perspective on critical issues, sustaining strategic sponsor relationships, and developing technology for both long-term interests and short-term, high-priority needs. The Laboratory supported approximately 680 sponsored programs for national security.

A few of the highlights are included below.

- The Laboratory demonstrated a coordinated autonomous formation of more than 100 miniature UAVs after they were dispensed from three F/A-18 Super Hornets.

- The Multi-look Airborne Collector for Human Encampment and Terrain Extraction (MACHETE) 3D ladar completed numerous real-world, operational sorties. It collects data on activities under heavy foliage, exploiting new noise-filtering and data-aggregation algorithms to produce imagery with dramatically improved resolution.

- A beam-combined fiber laser system demonstrated record brightness. The coherently combined beam was generated from 10s of optical fiber amplifiers and had near-ideal beam quality and high beam-combining efficiency.

- Advanced technologies were prototyped for a new airborne signals intelligence system that is currently being transferred to an industrial partner for production and fielding.

- The Laboratory completed the integration and test of a prototype compact airborne laser communications terminal that supports robust spatial tracking and near-theoretical communications performance against a low-average-power burst-mode signal.

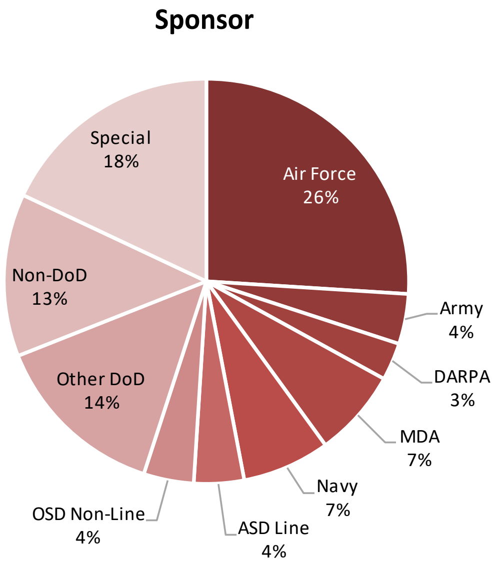
- Automated video analysis software developed for site security significantly accelerates the process of extracting information from videostreams.

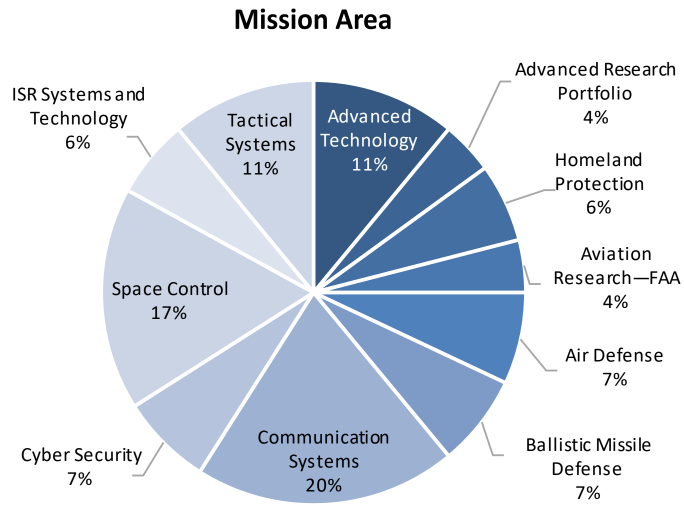
- The Laboratory developed advanced graph analytics algorithms to rapidly detect cyber threat actors within communication networks.

- The Laboratory fabricated, integrated, and tested the detector arrays and optical subsystem for the science payload that will be carried on the Transiting Exoplanet Survey Satellite on a mission to discover exoplanets. The payload was jointly developed by the MIT Kavli Institute for Astrophysics and Space Research and the Laboratory under funding from NASA.

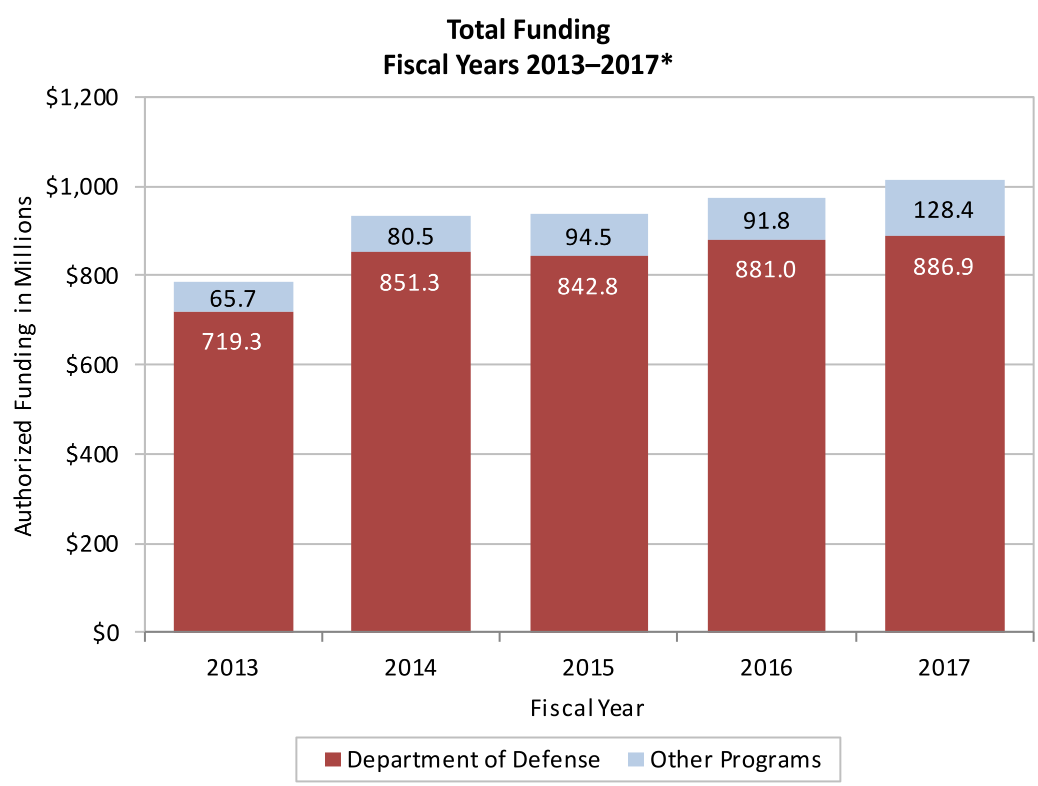
Breakdown of Laboratory Program Funding

Total Funding FY2017*= $1,015.3 million





DARPA: Defense Advanced Research Projects Agency
MDA: Missile Defense Agency
ASD: Assistant Secretary of Defense
OSD: Office of the Secretary of Defense
DoD: Department of Defense



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

Major Programs/Prototypes

Space Surveillance Telescope

Lincoln Laboratory's Near-Earth Asteroid Research (LINEAR) program supports NASA in fulfilling Congressional mandates to find and catalog by 2020 90% of near-Earth objects that have a diameter of 140 m or greater. In 15 years of operations, two 1 m ground-based electro-optical telescopes at White Sands Missile Range in New Mexico discovered 231,082 objects. Since January 2014, the LINEAR program has reported more than nine million observations of asteroids and comets. The surge in observations is due to the Space Surveillance Telescope (SST)—a highly capable telescope whose innovative curved focal plane enables deep, wide-area searches of the night sky. It detects small objects in geosynchronous orbits and achieves highly sensitive, rapid, wide-area sky surveys. The submission of 7.2 million observations in 2015 made the SST the most productive asteroid search instrument ever in terms of number of observations by a search program in a single calendar year. Since 2014, the SST has found 4,548 new objects, including four potentially hazardous objects and three new comets.

Localizing Ground-Penetrating Radar

Lincoln Laboratory has demonstrated the use of a novel subsurface map-based registration that offers the potential for low sensitivity to the limitations (snow, heavy rain, fog, or dirt) that cause optical sensors to fail to localize autonomous ground vehicles (AGVs) and perform accurate lane keeping. This technique, Localizing Ground-Penetrating Radar (LGPR), uses a new class of GPR technology to profile the environment below the road. The LGPR captures features such as soil layering and deeply buried rocks that are inherently static. From the underground features, the LGPR develops a map of the road's subsurface that is used as a reference for estimating an AGV's location on the road. In addition, VHF radio waves can penetrate through rain, fog, soil, dust, and snow. Because the LGPR deduces location on the basis of underground features, it can operate under conditions that incapacitate optical or infrared localization sensors, providing position estimates even if the AGV encounters severe weather, obscured or unpaved roads, disrupted or altered roads, or GPS-denied areas.

Major Technology Transfers

Cyber Security and Information Sciences

The Lincoln Adaptable Real-Time Information Assurance Testbed (LARIAT) was transitioned to a commercial startup company. Lincoln Laboratory's Secure High-Assurance Micro Crypto and Key-management (SHAMROCK) processor was transferred to a commercial partner in support of a USAF effort to develop foundations for agile and resilient embedded systems.

Intelligence, Surveillance, and Reconnaissance Systems and Technology

Open architecture technologies based on prototypes developed over the past several years for the USAF Distributed Common Ground System were transitioned to AFRL's Information Directorate.

Air, Missile, and Maritime Defense Technology

To support the MDA's initiative to improve homeland defense capabilities, the Laboratory is developing prototype flight articles that can be used to test the Ballistic Missile Defense System. The Laboratory successfully built and flight-tested prototype hardware; these designs are being transferred to industry for production and deployment on future flight tests. Several efforts for the U.S. Navy are focused on electronic countermeasures to defend ships against advanced antiship missile threats. A prototype for an advanced offboard countermeasure for ship-based defense has been completed, and technology from that prototype has been transitioned to the Navy.

Communication Systems

The fifth-generation advanced training waveform specifications, models, and the prototype implementation were transferred to defense industry participants in the USAF's Live, Virtual, and Constructive Advanced Technology Demonstration program. Lincoln Laboratory has transferred modem and optical terminal technology that will support the development of terminals for NASA's Laser Communications Relay Demonstration. The Laboratory worked with multiple industry vendors to validate subsystems that NASA will use for the terminals.

Lincoln Laboratory Mission Areas

Air and Missile Defense Technology

Lincoln Laboratory develops and assesses integrated systems for defense against ballistic missiles, cruise missiles, and air and maritime platforms in tactical, regional, and homeland defense applications. Activities in this mission area include the investigation of system architectures, development of advanced sensor and decision support technologies, development of pathfinder prototype systems, extensive field measurements and data analysis, and the verification and assessment of deployed system capabilities. A strong emphasis is on developing innovative solutions, maturing technologies, rapidly prototyping systems, and transitioning new capabilities for operational systems to the government and government contractors.

Communication Systems

Lincoln Laboratory is working to enhance and protect the capabilities of the nation's global defense networks. Emphasis is placed on synthesizing communication system architectures, developing component technologies, building and demonstrating end-to-end system prototypes, and then transferring this technology to industry for deployment in operational systems. Current efforts focus on radio-frequency (RF) military satellite communications, free-space laser communications, tactical network radios, quantum systems, and spectrum operations.

Cyber Security and Information Sciences

Lincoln Laboratory conducts research, development, evaluation, and deployment of cyber-resilient components and systems designed to ensure that national security missions can be accomplished successfully despite cyber attacks. Work in cyber security includes research; cyber analysis; architecture engineering; development and assessment of prototypes that demonstrate the practicality and value of new cyber protection, detection, and reaction techniques; and, where appropriate, deployment of prototype technology into operations. The Laboratory plays a major role in the design, development, and operation of large-scale cyber ranges and cyber exercises. In addition, the Laboratory develops advanced hardware, software, and algorithms for processing large, high-dimensional datasets from a wide range of sources, including speech, imagery, text, and network traffic. To facilitate this development, researchers employ high-performance computing architectures, machine learning for advanced analytics, and relevant metrics and realistic datasets.

Intelligence, Surveillance, and Reconnaissance Systems and Technology

To expand intelligence, surveillance, and reconnaissance (ISR) capabilities, Lincoln Laboratory conducts research and development in advanced sensing, signal and image processing, automatic target classification, decision support, and high-performance computing. By leveraging these disciplines, the Laboratory produces novel ISR system concepts for surface and airborne applications. Sensor technology for ISR includes passive and active electro-optical systems, surface surveillance radar, and RF geolocation. Increasingly, the work extends from sensors and sensor platforms to include the processing, exploitation, and dissemination technologies that transform sensor data into the information and situational awareness needed by operational users. Prototype ISR systems developed from successful concepts are then demonstrated and transitioned to industry and the user community.

Tactical Systems

Lincoln Laboratory assists the DoD in improving the development of various tactical air and counterterrorism systems through a range of activities that includes systems analysis to assess technology impact on operationally relevant scenarios, detailed and realistic instrumented tests, and rapid prototype development of U.S. and representative threat systems. A tight coupling between the Laboratory's efforts and DoD sponsors and warfighters ensures that these analyses and prototype systems are relevant and beneficial to the warfighter.

Space Control

Lincoln Laboratory develops technology that enables the nation to meet the challenges of an increasingly congested and contested space domain. The Laboratory develops and utilizes systems to detect, track, identify, characterize, and assess the growing population of resident space objects, and investigates technologies to improve monitoring of the space environment. Given the emerging potential for conventional conflict to extend to space, the Laboratory is examining space mission resilience to determine critical services and is assessing the impact of potential threats. The Laboratory is proposing alternative disaggregated architectures and prototyping advanced sensors and systems.

Advanced Technology

The Advanced Technology mission supports national security by identifying new phenomenology that can be exploited in novel system applications and by then developing revolutionary advances in subsystem and component technologies that enable key, new system capabilities. These goals are accomplished by a community of dedicated employees with deep technical expertise, collectively knowledgeable across a wide range of relevant disciplines and working in unique, world-class facilities. This highly multidisciplinary work leverages solid-state electronic and electro-optical technologies, innovative chemistry, materials science, advanced RF technology, and quantum information science.

Homeland Protection

The Homeland Protection mission supports the nation's security by innovating 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 either man-made or natural disasters. The broad sponsorship for the mission area spans the DoD, the Department of Homeland Security, and federal, state, and local entities. Recent efforts include humanitarian assistance and disaster response architectures and technologies, new microfluidic technologies for DNA assembly and transformation and for gene synthesis, improvement of the detection and classification for air vehicle threats, and technologies for border and maritime security.

Aviation Research

Since 1971, Lincoln Laboratory has supported the FAA in the development of new technology for air traffic control. This work initially focused on aircraft surveillance and weather sensing, collision avoidance, and air-ground data link communication. The program has evolved to include safety applications, decision support services, and air traffic management automation tools. The current program is supporting the FAA's Next Generation Air Transportation System (NextGen). Key activities include development of the next-generation airborne collision avoidance system; refinement and technology transfer of NextGen weather architectures, including cloud processing and net-centric data distribution; and development of standards and technology supporting unmanned aerial systems' integration into civil airspace.

Advanced Research Portfolio

Internal research and development at Lincoln Laboratory is supported through congressionally appropriated funding, known as the Line, administered by the office of the Assistant Secretary of Defense for Research and Engineering. 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.

The projects supported by the Line are organized according to technology categories that have been selected to address gaps in existing and envisioned mission areas. Nine technology categories were selected to include both core and emerging technology initiatives. There are currently five core-technology areas in the Advanced Research Portfolio: advanced devices; optical systems and technology; information, computation and exploitation; RF systems and technology; and cyber security. In addition, there are four emerging-technology initiatives: novel and engineered materials, quantum system sciences, biomedical sciences, and autonomous systems.

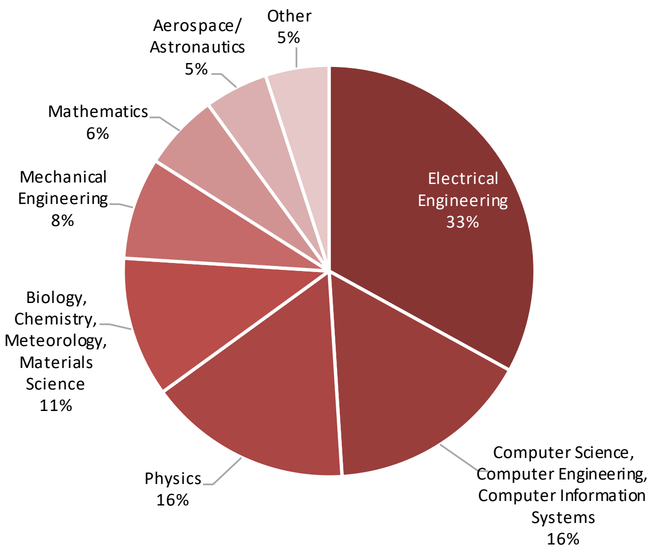
Lincoln Laboratory Technical Staff

Lincoln Laboratory employs 1,823 technical staff, 544 technical support personnel, 1,168 support personnel, and 516 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.

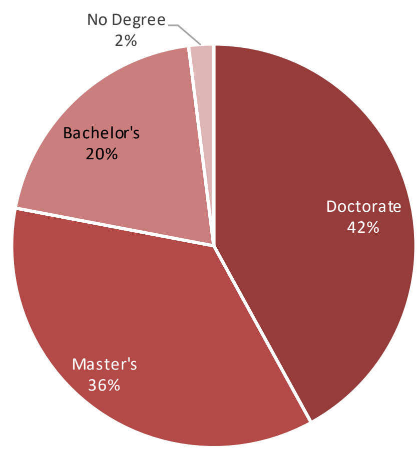
Lincoln Laboratory recruits at more than 60 of the nation's top technical universities, with 65 to 75% of new hires coming directly from universities. Lincoln Laboratory augments its campus recruiting by developing long-term relationships with research faculty and promoting fellowship and summer internship programs.

Composition of Professional Technical Staff

Academic Disciplines of Staff



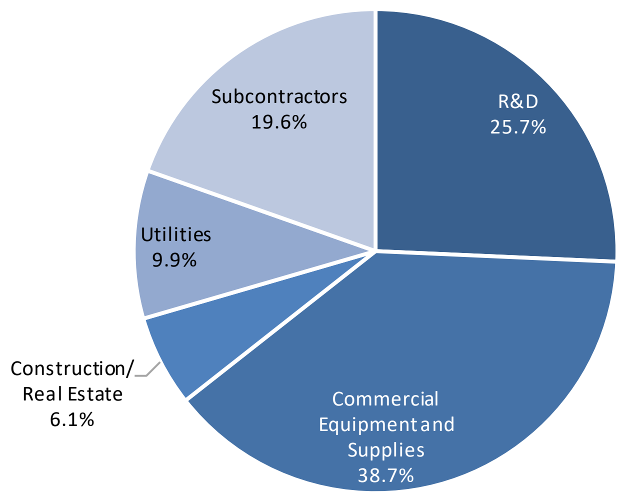
Academic Degrees Held by Staff



Lincoln Laboratory's Economic Impact

During fiscal year 2017, the Laboratory issued subcontracts with a value of approximately $522 million. The Laboratory awarded subcontracts to businesses in all 50 states. Massachusetts businesses were awarded $203 million in contracts, and states as distant as Colorado and Arizona also realized significant benefits to their economies.

Contracted Services (FY2017)*



*Estimates from $522.2M, total FY2017 spend.
- Includes orders to MIT ($32.2M)
- 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 2016. Lincoln Laboratory expanded the number of noncredit courses organized and led by its technical staff members to eight activities. 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 2016, eight undergraduates were hired as UROP interns and four 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 an engine for innovative research and a mechanism for expanding project-based learning opportunities for students. By leveraging the expertise of MIT faculty, researchers, and Lincoln Laboratory staff, 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 tools and 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 local K–12 schoolchildren. In 2016, nine groups were involved in different science, technology, engineering, and mathematics (STEM) programs held at the center, including a build-a-radar workshop directed by instructors from the Lincoln Laboratory; weekly practices for the Lincoln Laboratory teams that participate in the national CyberPatriot computer-network security challenges; and an ongoing mentorship program with the Community Charter School of Cambridge.

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 Facility houses several Lincoln Laboratory–operated aircraft used for rapid prototyping of airborne sensors and communications.


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

Other Sites
Other sites include the Pacific Missile Range Facility in Kauai, Hawaii and the Experimental Test Site in Socorro, New Mexico.

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 of our most successful programs are listed below.

LLRISE

Nine technical staff members taught various portions of the sixth 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 computer-aided design, 3D printing, circuit board assembly, electromagnetics, pulse compression, signal processing, antennas, and MATLAB, electronics.

LLCipher

Lincoln Laboratory's one-week workshop, LLCipher provides an introduction for high-school students to modern cryptography—a math-based, theoretical approach to securing data. Lessons in abstract algebra, number theory, and complexity theory provided students with the foundational knowledge needed to understand theoretical cryptography.

CyberPatriot

Lincoln Laboratory sponsored three teams in CyberPatriot, a national competition for high-school students learning defensive computer security. The students were mentored by Laboratory staff. After learning how to identify malware, "clean" a computer system, and establish a secure network, the teams competed in the statewide competition. One team advanced to the Northeast regional competition.

Lincoln Laboratory Outreach in 2016

50 EDUCATIONAL OUTREACH **STEM** PROGRAMS IN K–16

7 NEW EDUCATIONAL OUTREACH PROGRAMS

5 NEW LABORATORY PROGRAMS FOR UNDERGRADUATE **INTERNSHIPS**