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.

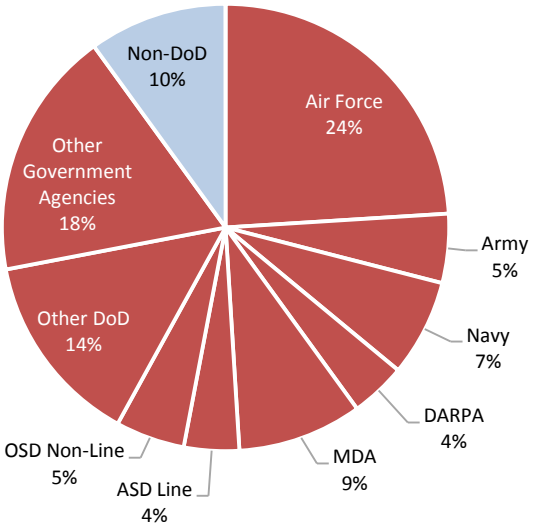
Over the past year, Lincoln Laboratory reached milestones in several areas:

- A prototype of a low-cost, multifunction phased array radar is expected to become the basis for upgrades to air traffic control and homeland protection radars across the country.
- Transitioned into operations the Multi-look Airborne Collector for Human Encampment and Terrain Extraction (MACHETE), a 3D ladar system designed to uncover hidden activity in heavily foliated areas. MACHETE has already been used in more than 160 sorties overseas.
- A new space-based sensing capability will better protect U.S. systems.
- Demonstrated the first flight of a large number of self-organizing unmanned aerial vehicles for new defense system protection needs.
- A novel adaptive antenna array antenna will give aircraft an enhanced communications capability in highly contested electromagnetic environments.
- Demonstrated the largest short-wave-infrared focal plane array capable of detecting individual photons. This array will be used in new airborne and space-based sensor applications.
- New techniques for secure and resilient cloud computing were developed and demonstrated.
- Exploited Laboratory's high-density, three-dimensional wafer-scale integration technology to develop novel circuits that convert electrical signals into optical signals for rapid data distribution.
- Three of Lincoln Laboratory's technologies were recognized with R&D 100 Awards, given by R&D Magazine to the year's 100 most innovative technologies. Lincoln Laboratory has received 26 R&D 100 Awards over the past six years.

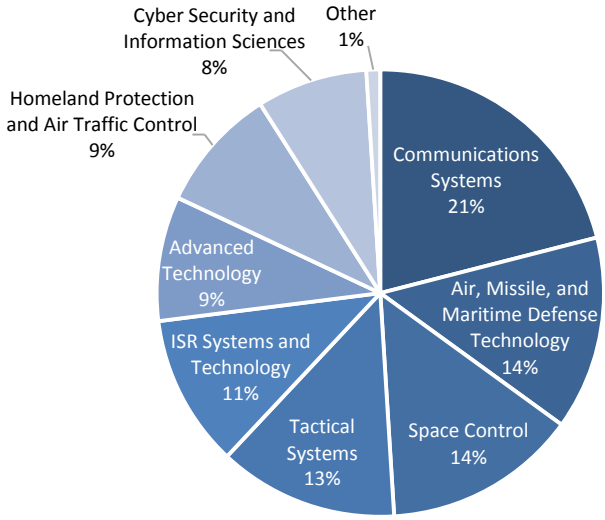
Funding FY2015*
Total Funding = $937.3 million

Breakdown of Laboratory Program Funding

Sponsor

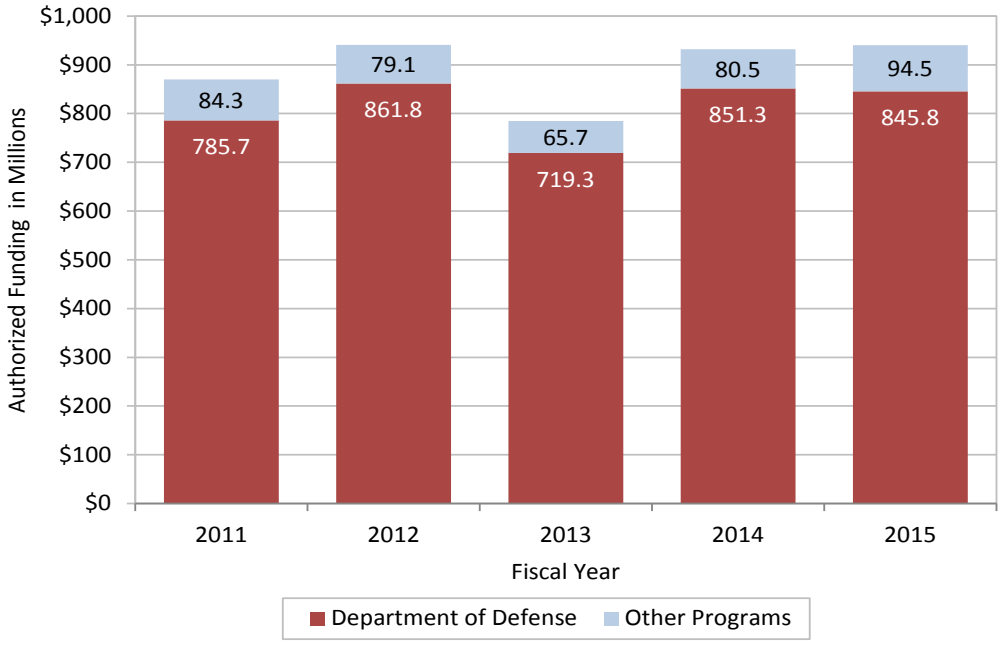


Mission Area



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

Total Funding
Fiscal Years 2011–2015*



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

Major Programs/Prototypes

Multi-look Airborne Collector for Human Encampment and Terrain Extraction

Capable of collecting unobscured 3D imagery from an altitude of 25 kft and at an incredible area coverage rate (400 km^2/hr at 25 cm resolution), MACHETE (Multi-look Airborne Collector for Human Encampment and Terrain Extraction) can peek through openings in dense canopy to form detailed images of natural and man-made structures existing at and near the ground level, mapping out city-scale areas in minutes. For a heavily forested area with 90% canopy cover that is the size of Central Park, MACHETE can provide detailed images of every building, footbridge, and walkway below the canopy at 25 cm resolution in approximately five minutes.

The canopy can be digitally "defoliated" to reveal the structures underneath at any selected height above ground. Time-of-flight measurement is combined with pointing information of MACHETE's gimbaled scanning system and the position of the airborne platform to produce a geolocated 3D point-cloud image. The imagery is color-coded to indicate differences in scene elevation, with color brightness indicating the intensity of the reflected light. Advanced onboard processing and analysis algorithms enable the classification of features of interest.

Real-time Open Systems Architecture for Reagan Test Site Sensor Systems

Lincoln Laboratory designed, developed, and implemented a new Real-time Open Systems Architecture (ROSA II) technology that is improving the efficacy of the radar and optical sensors at the Reagan Test Site on the Kwajalein Atoll in the Marshall Islands.

ROSA II extends the open concept to all sensor and control system software and offers a previously unachieved level of real-time data accessibility and system control, allowing for netcentric operation at the sensor and provides an ability to rapidly implement new software functions or to substitute existing functions from other systems built with ROSA II. It enables the interoperability of diverse hardware and software components, so systems are not constrained to only one operating platform or only system-specific components.

Major Technology Transfers

Advanced Technology
A world-leading superconducting microelectronic process was made available to industry performers.

Air Traffic Control
Lincoln Laboratory is supporting the transition of a prototype ground-based sense-and-avoid system to the U.S. Army. The system will undergo deployment to five Army Gray Eagle operational sites this year.

Future technology transfer will be supported on an annual basis. Decision support tools are being transferred into the Federal Aviation Administration's Traffic Flow Management System through 2020. These tools provide 0–2-hour forecasts of convective weather impact on terminal arrival routes and use wind, ceiling, and visibility forecasts and airport-specific operating procedures to aid in setting airport arrival rate targets.

Communication Systems
Lincoln Laboratory transferred a software implementation of the Dynamic Link Exchange Protocol to a group of three companies developing advanced communication systems. The protocol, which is undergoing standardization in the Internet Engineering Task Force, an international community of network researchers, will provide improved queuing and flow control for wireless networks.

An advanced algorithm for fast computation of wireless communications interference in radio networks was transitioned into two commercial wireless network simulation software frameworks. These frameworks are widely used in commercial and defense industry communications engineering to model wireless systems and to evaluate the performance of network and routing protocols.

Intelligence, Surveillance, and Reconnaissance Systems and Technology
As part of its program for upgrading U.S. submarine sonars, Lincoln Laboratory transitioned adaptive beamforming, detection processing, and ranging algorithms, as well as improved collision warning indicators, to the Navy.

The Laboratory delivered to the Air Force Research Laboratory several advanced software capabilities to enhance processing, exploitation, and dissemination capabilities for Air Force Distributed Common Ground Systems.

Tactical Systems
The Laboratory has developed a tactical intelligence, surveillance, and reconnaissance sensor for small unmanned aerial vehicles (UAV). The sensor provides actionable information in real time, significantly improving the response time over currently fielded systems. The sensor has been integrated onto a tactical UAV platform in cooperation with industry partners, and hardened prototypes have been transitioned to the Army for operational use. Development is continuing to extend the payload for use on both moving and stationary platforms.

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 vehicles in tactical, regional, and homeland defense applications. Activities include the investigation of system architectures, development of advanced sensor and decision support technologies, development of flight-test hardware, extensive field measurements and data analysis, and the verification and assessment of deployed system capabilities. A strong emphasis is on rapidly prototyping sensor and system concepts and algorithms, and transferring resulting technologies to government contractors responsible for developing operational systems.

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 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 prototype components and systems designed to improve the security of computer networks, hosts, and applications. Efforts include cyber analysis; creation and demonstration of architectures that can operate through cyber attacks; development of prototypes that demonstrate the practicality and value of new techniques for cryptography, automated threat analysis, anti-tamper systems, malicious-code detection; and deployment of prototype technology to national-level exercises. Complementary advanced hardware, software, and algorithm technologies are developed for processing large, high-dimensional datasets from a wide range of sources. In the human language technology area, emphasis is placed on realistic data and experimental evaluation of techniques for speech recognition, dialect identification, speech and audio signal enhancement, and machine translation.

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 systems, and high-performance computing. By leveraging these disciplines, the Laboratory produces novel ISR system concepts for both surface and undersea applications. Sensor technology for ISR includes passive and active electro-optical systems, surface surveillance radar, radio-frequency geolocation, and undersea acoustic surveillance. 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 transitioned to industry and the user community.

Tactical Systems

Lincoln Laboratory assists the Department of Defense (DoD) in improving the development and employment of various tactical air and counterterrorism systems through a range of activities that include 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's space surveillance system to meet the challenges of space situational awareness. The Laboratory works with systems to detect, track, and identify man-made satellites; collects orbital-debris detection data to support space-flight safety; performs satellite mission and payload assessment; and investigates technology to improve monitoring of the space environment, including space weather and atmospheric and ionospheric effects. The technology's emphasis is the application of new components and algorithms to enable sensors with greatly enhanced capabilities and to support the development of netcentric processing systems for the Nation's Space Surveillance Network.

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 radio frequency technology, and quantum information science.

Homeland Protection

The Nation's security is supported by Lincoln Laboratory's innovative technology and architectures that help prevent terrorist attacks within the United States, reduce the vulnerability of the nation to terrorism, minimize the damage from terrorist attacks, and facilitate recovery from either man-made or natural disasters. The broad sponsorship for this mission area spans the DoD, the Department of Homeland Security, and other federal, state, and local entities. Recent efforts include architecture studies for the defense of civilians and facilities, new microfluidic technologies for DNA assembly and transformation and for gene synthesis, improvement of the Enhanced Regional Situation Awareness system for the National Capital Region, the assessment of technologies for border and maritime security, and the development of architectures and systems for disaster response.

Aviation Research

Since 1971, Lincoln Laboratory has supported the Federal Aviation Administration (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 supports 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 netcentric data distribution; and the 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 Laboratory's 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.

Projects supported by the Line are organized according to technology categories that are selected to address gaps in existing and envisioned mission areas. Nine technology categories were selected to include both core and emerging technology initiatives. Currently, five core-technology areas are 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.

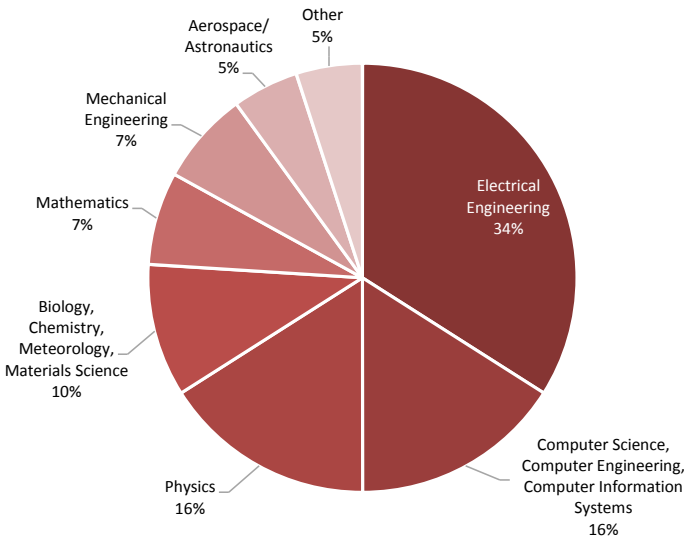
Lincoln Laboratory Technical Staff

Lincoln Laboratory employs 1,740 technical staff, 433 technical support personnel, 1,055 support personnel, and 520 subcontractors. Three-quarters of the technical staff have advanced degrees, with 42% holding doctorates. Professional development opportunities and challenging cross-disciplinary projects are responsible for the Laboratory's ability to retain highly qualified, creative staff.

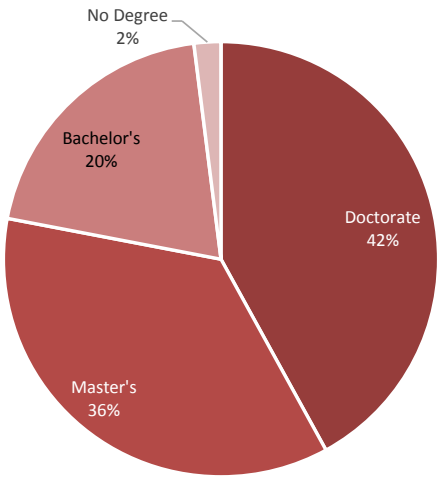
Lincoln Laboratory recruits at more than 60 of the Nation's top technical universities, with 65 to 75% of new hires coming directly from universities. Lincoln Laboratory augments its campus recruiting by developing long-term relationships with research faculty and promoting fellowship and summer internship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

Composition of Professional Technical Staff

Academic Disciplines of Staff



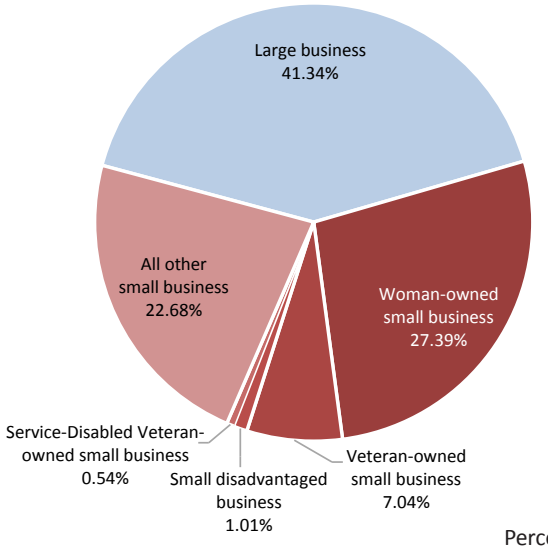
Academic Degrees Held by Staff



Lincoln Laboratory's Economic Impact

During fiscal year 2015, the Laboratory issued subcontracts with a value of approximately $600 million. The Laboratory awarded subcontracts to businesses in all 50 states and purchased more than $351 million in goods and services from New England companies in 2015, with Massachusetts businesses receiving approximately $293 million. Economies in states as distant as California and Texas also realized significant benefits due to the Laboratory. More than 58% of Laboratory subcontracts were awarded to small businesses of all types in 2015.

Contract Award by Category of Business (FY2015)*



Percentage small business: 58.66%

*As reported to the Defense Contract Management Agency (DCMA). Lincoln Laboratory fiscal year runs concurrent with the U.S. Government fiscal year, October 1–September 30.

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 2015. Lincoln Laboratory expanded the number of noncredit courses organized and led by its technical staff members to seven activities. Many of this year's IAP noncredit activities were held at Beaver Works.

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 to 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. In 2015, five VI-A students participated 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 2015, twelve undergraduates were hired as UROP interns and seven 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, students and 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 at the center of which is a project to develop technology that solves a real-world problem identified by Lincoln Laboratory researchers. 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. MIT undergraduate and graduate students participated in the Assistive Technologies Hackathon (ATHack) at Beaver Works. Teams of students prototyped engineering solutions to problems faced by the disabled, such as a voice-activated cane and a hands-free walker.

Beaver Works extends project-based learning to local K–12 schoolchildren. In 2015, 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

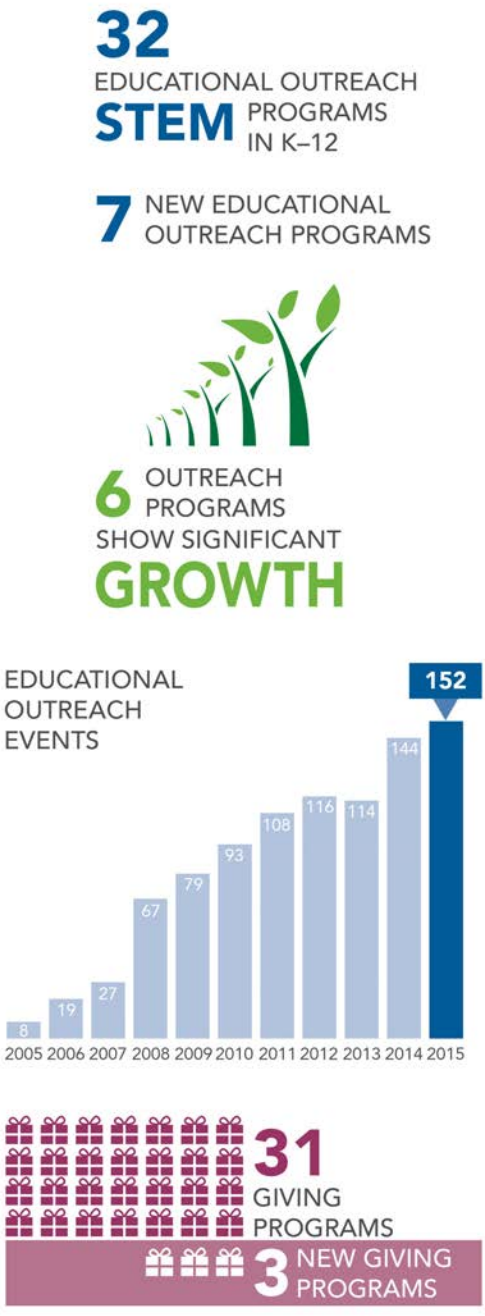
Other Sites

Pacific Missile Range Facility, Kauai, Hawaii
Experimental Test Site, 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' desires to help people in need and to motivate student interest in science, technology, engineering, and mathematics (STEM).The Laboratory accommodates an increasing number of outreach programs each year.

Lincoln Laboratory Outreach in 2015



Some of our most successful programs are listed below.

LLRISE

Nine technical staff members taught various portions of the fourth 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, MATLAB programming, electronics, and the principles of physics. Participants resided on the MIT campus, where they received advice on the college admissions process.

LLCipher

Lincoln Laboratory's new 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 provide 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 14 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.

Wearables Workshop

Lincoln Laboratory's Kristen Railey presented a full-day workshop to introduce high-school girls to engineering by having them make their own wearables—apparel and accessories that incorporate computer and electronic technologies. The girls left the workshop with 3D-printed bracelets but also with basic skills in computer-aided design (CAD), computer programming, and circuitry. The girls learned about the applications of 3D printers; attended a session on CAD software; and programmed light-emitting diodes for a shoe-wearable electronic circuit that they built.