Lincoln Laboratory

Lincoln Laboratory is a Department of Defense (DOD) federally funded research and development center operated by MIT. Under a prime contract with the US Department of the Air Force, Lincoln Laboratory conducts research and development on behalf of the military services, the Office of the Secretary of Defense, the intelligence community, and other government agencies.

Lincoln Laboratory's mission is to advance system and technology development in support of national security. The majority of the research and development carried out at the Laboratory is in the areas of sensors, integrated sensing, information extraction (signal processing and embedded computing), decision support, and communications, all supported by a broad research base in advanced electronics. Projects focus on developing and prototyping new technologies and capabilities to meet DOD needs that cannot be met as effectively by existing government or contractor resources.

The Laboratory maintains its relevance by continually leveraging its expertise to meet new challenges presented by the evolving needs of the nation and its military forces. Cyber security, critical to protecting the vast amounts of diverse digital data, is a growing mission area. Demand for intelligence, surveillance, and reconnaissance (ISR) systems remains strong, and interest in capabilities for autonomous systems is high. The Laboratory is applying its competencies in advanced signal and image processing, electronics and optics, complex system analysis, and biological defense to developing advanced biomedical technologies and systems to address national healthcare needs and enhance soldier fitness and resilience. Research into quantum information sciences is yielding more powerful ways to process information; current work is focused on superconducting quantum bits (qubits), trapped-ion qubits, and quantum photonic technologies. Rapid prototyping efforts continue to be important elements of the Laboratory's portfolio.

For the fiscal year July 1, 2012, to June 30, 2013, Lincoln Laboratory received approximately $769 million to support the efforts of approximately 1,735 professional technical staff and 2,085 support personnel and subcontractors; outside procurement will exceed $415 million. Although most of the research is sponsored by DOD, funding is also received from the Federal Aviation Administration (FAA), the National Aeronautics and Space Administration (NASA), the Department of Homeland Security (DHS), and the National Oceanographic and Atmospheric Administration (NOAA). In addition, Lincoln Laboratory also carries out noncompetitive research with industry under approved cooperative research and development agreements and other collaborative activities with academic institutions.

On April 1, 2010, the Department of Defense awarded a five-year reimbursement contract option to MIT for the operation and management of Lincoln Laboratory as federally funded research and development center. The award continues the long-standing relationship that has existed between the US government and MIT, which has operated Lincoln Laboratory since its establishment.

Laboratory Operations

Lincoln Laboratory operations are marked by the following fundamental attributes: high-caliber staff, streamlined organizational structure, high-quality infrastructure, well-defined strategic focus, and strong alignment with the MIT campus.

Organization

Lincoln Laboratory's success has been built on the core values of technical excellence and integrity, which are exemplified by the Laboratory's exceptional staff. The three-tiered organizational structure—director's office, divisions and departments, and groups—encourages interaction between staff and line management (see Figure 1). Sponsors' interest in conducting research and development of more complex integrated systems has raised the level of collaboration between divisions. In addition, service departments, as providers of standardized support, and the safety and Mission Assurance and Program Support Office, as primary advisor, enable cross-divisional research teams to coordinate and manage the technical and programmatic challenges of large-scale developments.

Changes to the Laboratory's Structure

In January 2013, the Communication Systems and Cyber Security Division was restructured into two divisions. The Laboratory's portfolio of work in cyber security technology and information sciences has expanded over the past few years because of the increasing importance of these fields to national security. The new division, Cyber Security and Information Sciences, was established to focus on solutions to the challenges presented by the increasing reliance on digital data. The division's activities encompass cyber security, human language technology, large-scale analytics, and novel computing architectures. The Communication Systems Division remains the Laboratory's center of excellence in communication technologies that advance the capabilities of the nation's defense networks, focusing on research and development in military satellite communications, free-space laser communications, ground- and air-based tactical radios, and quantum technologies for communications.

Changes to Leadership

Director's Office: C. Scott Anderson was appointed assistant director for operations to begin on July 15, 2013. He joins Lincoln Laboratory after serving as the director of integration for acquisition in MITRE's National Security Engineering Center.

Cyber Security and Information Sciences Division: Stephan B. Rejto was appointed head of the new division. Formerly Rejto was assistant head of the Communication Systems and Cyber Security Division. Dr. Marc A. Zissman, a former assistant head in Communication Systems and Cyber Security, and David R. Martinez, formerly a principal researcher in that division, were named associate heads of Cyber Security and Information Sciences.

Communication Systems Division: Dr. James Ward moved from assistant head of the Intelligence, Surveillance, and Reconnaissance and Tactical Systems Division to assistant head of communications systems.

ISR and Tactical Systems Division: Dr. Justin J. Brooke was named assistant head of the ISR and Tactical Systems Division.

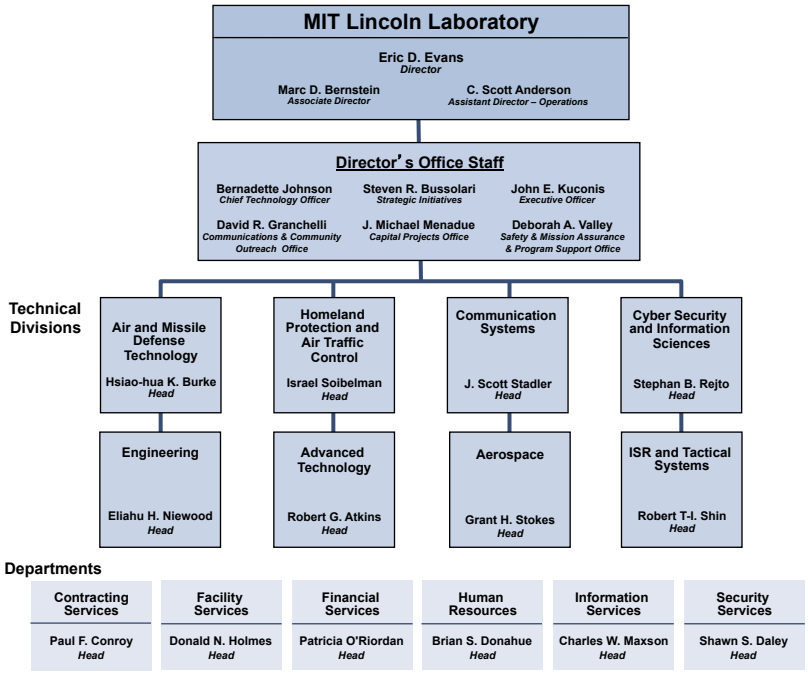

Figure 1. MIT Lincoln Laboratory organizational structure.

Staff

Key to maintaining excellence at Lincoln Laboratory is its technical staff of highly talented scientists and engineers. The laboratory recruits at colleges and universities nationwide. Sixty-five to 75 percent of the laboratory's new professional technical staff are hired from the nation's leading technical universities. The makeup of the Laboratory staff by degree and academic discipline is shown in the following charts.

Composition of Lincoln Laboratory Staff

Professional technical staff	1,736
Support staff (including technical support personnel)	1,514
Subcontractors	571
Total laboratory employees	3,821

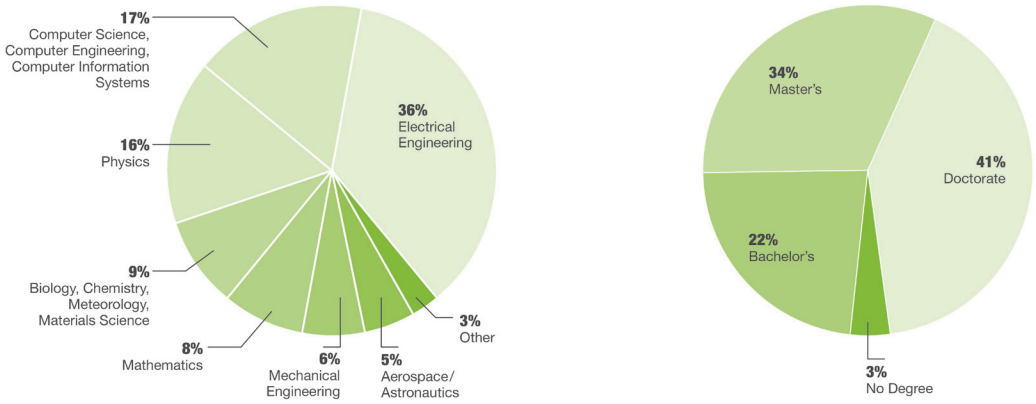

Figure 2. Composition of professional technical staff by (a) academic discipline and (b) academic degree.

Staff Honors and Awards

During the past year, several Lincoln Laboratory staff members were recognized for achievements in their fields and for their commitment to professional activities.

Dr. Hsiao-hua K. Burke was elected a fellow of the American Institute of Aeronautics and Astronautics for her "outstanding leadership in the development of missile defense systems, hyperspectral imaging technology and algorithms, and satellite systems for military and civilian applications."

Dr. Paul W. Juodawlkis was named a fellow of the Optical Society of America for "significant contributions to optically sampled analog-to-digital conversion and the development of the slab-coupled optical waveguide amplifier."

Dr. Clifford J. Weinstein and Dr. Helen H. Kim received MIT Lincoln Laboratory 2012 Technical Excellence Awards.

Laura A. Kennedy and Dr. Jason R. Thornton received 2012 MIT Lincoln Laboratory Early Career Technical Achievement Awards.

Dr. Peter L. Cho and Professor Noah Snavely of Cornell University received the 2012 MIT Lincoln Laboratory Best Paper Award for "Enhancing Large Urban Photo Collections with 3D Ladar and GIS Data," accepted for publication in the *International Journal of Remote Sensing Applications*.

Dr. Roger I. Khazan, Dr. Joshua I. Kramer, Daniil Utin, Dr. M. Michael Vai, and Dr. David J. Whelihan received the 2012 MIT Lincoln Laboratory Best Invention Award for development of the Self-contained High Assurance MicRO Crypto and Key-management (SHAMROCK) processor, for which a patent application was filed in July 2012.

Dr. John A. Tabaczynski received the 2012 Jamieson Award for his "outstanding contributions to Ballistic Missile Defense Programs." The award is presented by the Military Sensing Symposium on Missile Defense Sensors, Environments, and Algorithms.

Dr. Pascale M. Gouker was elected to a three-year term as secretary of the Radiation Effects Steering Group of the Institute of Electrical and Electronics Engineers (IEEE) Nuclear and Plasma Sciences Society.

Professional Development

Lincoln Laboratory's commitment to the professional development of its staff is seen in the diversity of opportunities presented through the Human Resources Department's educational program, the Technology Office, and the library.

The Human Resources Department coordinates programs in graduate education, technical education, professional leadership development, and computer and software training. For highly qualified candidates, the Laboratory offers the opportunity to apply to the Lincoln Scholars program, which supports the full-time pursuit of advanced degrees. The candidates accepted into the program perform their thesis research work at the Laboratory while serving as contributing members of the staff. This year, under the Lincoln Scholars program, five staff members earned advanced degrees. There are 29 staff members enrolled in the Lincoln Scholars program.

The Graduate Education Committee also coordinates distance learning programs—master's degree programs in information technology and in information science with a focus on cyber forensics and incident response from Carnegie Mellon University, and a master's degree program in information sciences from Pennsylvania State University. Currently, three people are enrolled in the distance learning programs.

The technical education program offers semester-length courses taught by Lincoln Laboratory technical staff or by outside experts, often professors from MIT. The 2012–2013 schedule included the following courses:

- Optical Systems Overview
- Signal Processing on Databases
- Theory and Methods for Modern Graph Analysis
- Decision Making Under Uncertainty
- Patterns and Anti-patterns for Service-oriented Architecture
- Systems Engineering at MIT Lincoln Laboratory

The professional and leadership development program again sponsored courses in leadership techniques, project management, preparing presentations, and scientific and technical writing. Computer training in common software applications (Word, PowerPoint, Excel, Illustrator, and Photoshop, etc.) and in technical software (MATLAB, Simulink, VxWorks, etc.) is offered on-site throughout the year.

The Technology Office coordinates an extensive program of seminars that are presented at Lincoln Laboratory by both in-house speakers and researchers from universities and industry. The seminars are chosen to reflect current and leading-edge trends in today's technology. The Technology Office Seminar Series invites today's leading scientists to present their ideas to laboratory staff throughout the year. The special seminars are less frequent but often spotlight nationally known experts, while the Lincoln Laboratory on campus series, Technology in Entertainment series, and other focus-specific series provide detailed insights on technologies that are outside the laboratory's core research interests. Highlights of the 2012–2013 seminar program include the following:

- "Fun and Horror from the Trenches of Game Tech," Eric Malafeew, cofounder and engineering director at Harmonix Music Systems
- "Transiting Exoplanets: From Ground-based Origins to Kepler Discoveries and Beyond," professor Sara Seager, MIT
- "Mathematica, Wolfram/Alpha, and the Next Steps in Computation," Dr. Stephen Wolfram, founder and chief executive officer of Wolfram Research
- "Going Big on Big Data," professor Sam Madden, MIT's Computer Science and Artificial Intelligence Laboratory
- "Semiconductor Quantum Technologies for Information Processing and Precision Measurements," professor Dirk Englund, MIT
- "Innovation in Sports and Technology," Chuck Pagano, chief technology officer, ESPN

Diversity and Inclusion

The Laboratory continues to foster an inclusive workplace that leverages and supports the talents and perspectives of the Laboratory's staff. Recruitment at a broad range of universities, programs in mentoring, affinity groups such as the New Employee Network, and flexible work options are contributing to the hiring and retaining of a more diverse workforce.

In February, Lincoln Laboratory held a Diversity Summit that addressed ways to foster an inclusive workplace. Guest speaker Dr. Kristin Lane, assistant professor of psychology at Bard College, discussed her research findings on how unconscious biases people hold present a hurdle to creating an inclusive environment. Six Laboratory staff members extended the conversation with a panel discussion on solutions to bias-related issues.

Four formal mentorship programs that had been established in early 2011 and phased in during 2011–2012 continued. The New Employees Guides, Early Career Mentoring, Circle Mentoring, and New Assistant Group Leader Mentoring programs provide employees with support during different stages of their careers. Since 2011, 670 "mentees" have participated in the programs (excluding the guides program, in which all new employees are initially enrolled). The mentoring programs have helped enhance employees' professional development and have contributed to the Laboratory's ability to retain a diverse workforce.

Employee resource groups at Lincoln Laboratory help create an inclusive environment. Two new resource groups were founded in spring 2013: the Lincoln Employees' African-American Network (LEA^{2}N) and Lincoln Laboratory Out Professionals and Employees Network (LLOPEN). These groups are joining the new employee, technical women, Hispanic and Latino, and veterans networks to offer mentoring, help with adjusting to life in New England, and opportunities to participate in outreach activities.

The Diversity and Inclusion Subcommittee of the Laboratory's Professional and Community Enhancement Committee was initiated to develop activities that promote an environment of acceptance and mutual respect. The subcommittee organizes educational, social, and networking events that promote collaboration and cultural awareness. During 2012–2013, the subcommittee hosted several speakers in coordination with diversity month celebrations. Speakers included Dr. Amber Straughn, an astrophysicist from NASA's Goddard Space Flight Center, who spoke on her work on the James Webb Space telescope; Professor Emma Teng, professor of Asian civilizations and Chinese studies at MIT, who examined historical stereotypes about Asians; Gregg Ames of the Massachusetts Rehabilitation Commission, who discussed ways to help people with disabilities feel welcome at work; and Tom Bourdon, director of the LGBT Center at Tufts, who reviewed the workplace issues confronted by lesbian, gay, bisexual, and transgendered employees. These events raised awareness of the contributions of underrepresented groups.

Technical Program Highlights

Research and development at the Laboratory focus on national security problems in diverse areas: tactical and intelligence, surveillance, and reconnaissance systems, air and missile defense, space situational awareness, chemical and biological defense, communications, cyber security, and advanced electronics technology. In addition, the Laboratory undertakes related nondefense work in areas such as air traffic control, weather sensing, and environmental monitoring for agencies such as the FAA, NASA, and NOAA. A principal activity of the Laboratory's technical mission is the development of components and systems for experiments, engineering measurements, and tests under field operating conditions.

During 2012–2013, the Laboratory worked on approximately 610 sponsored programs that range from large-scale hardware projects to small "seedling" initiatives. Notable highlights for each mission area are listed below.

Space Control

The space surveillance telescope (SST), a 3.5 m telescope for searching deep space, neared completion of full checkout prior to its inclusion in the US Space Surveillance Network. The SST achieved first light in 2011, and satellite tracking was demonstrated with excellent metric accuracy, sensitivity, and search capability. Several unique capabilities, including autonomous operations and the end-to-end, satellite detection/tracking/correlation data processing pipeline, were also demonstrated during checkout.

Figure 3. The fully assembled Space Surveillance Telescope.

After the X-band transmitter and receiver electronics of the Haystack Ultrawideband Satellite Imaging Radar were reintegrated, the radar demonstrated successful X-band operation. Antenna-surface refinement, required for W-band operations, is expected to be completed in 2013.

NASA selected Lincoln Laboratory to fly a demonstration sensor package on a CubeSat bus in 2014. The CubeSat and sensor package that is being developed by Lincoln Laboratory and MIT will serve as a pathfinder for future civilian and DOD-distributed weather-sensing systems, dramatically reducing cost, schedule, and risk while improving performance and robustness.

Continuing its history of significant contributions to the nation's environmental monitoring needs, Lincoln Laboratory began assessing the performance of the atmospheric sounding sensor suite on the Joint Polar Satellite System, launched in October 2011. The Laboratory has supported this system since its inception in the 1990s. Performance results to date are exceeding all specifications. Data from this new system may enable novel sounding algorithms, leading to substantial improvements in processing and performance.

Air and Missile Defense Technology

A prototype for an airborne infrared processor was integrated with a multispectral sensor to demonstrate real-time image processing and data extraction, automatic acquisition, and hands-free closed-loop tracking on the ground. The processing technology was transferred to Raytheon and subsequently flew on a manned airborne platform to track space objects and ballistic missiles.

Figure 4. The Camcopter (top) is being considered as a possible unmanned aerial platform for an advanced electronic warfare capability for the Navy. The Laboratory is prototyping the electronic attack payload, including an advanced, wideband, scanning, dual-polarized antenna array (bottom) and a modular, channelized processing chain.

As the Missile Defense Agency's (MDA) counter-countermeasures chief scientist, Lincoln Laboratory leads MDA's technical efforts for defining discrimination solutions. Current efforts focus on developing a robust approach to missile defense lethal target identification and enforcement requirements for regional and theater threats.

The Laboratory conducted significant design and risk-reduction efforts for radar environmental characterization and clutter mitigation. These efforts will enhance the capability of MDA's X-band radars. Clutter mitigation algorithms have been extensively tested in modeling and simulation, and will be demonstrated during upcoming flight tests.

Communication Systems

The Advanced Extremely High-Frequency (AEHF) calibration facility/interim command-and-control terminals developed by Lincoln Laboratory established the first on-orbit protected communications with the AEHF-1 satellite and successfully performed the high-fidelity radiometric measurements needed to calibrate the payload's antennas.

A small-form-factor protected satellite communications (SATCOM) modem for ground-based SATCOM-on-the-move applications was demonstrated. The modem includes the first information assurance architecture that is compliant with the new security classification guide for extremely high-frequency SATCOM. In addition, using only ground-segment enhancements, the Laboratory demonstrated adaptive coding techniques that have the potential to increase the capacities of existing communications satellites by up to an order of magnitude.

Recent air-to-ground laser communications (lasercom) demonstrations provided the first reported experimental evidence of scintillation reciprocity between single-mode receivers with near-unity correlation between power measurements at the receivers over a variety of channel conditions.

The Lunar Laser Communication Demonstration Program is on track to deliver lasercom terminals for NASA's first demonstration of optical communications. The link between NASA's satellite in a lunar orbit and Earth will be the longest-distance, free-space, optical communications ever achieved.

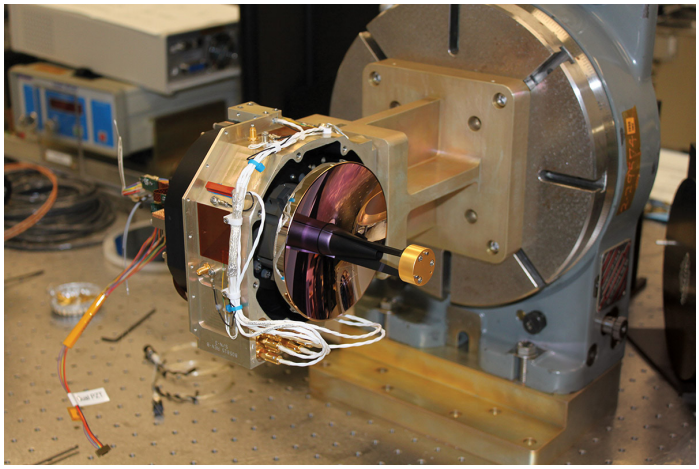

Figure 5. The assembled telescope and optical bench assembly for the lunar laser communication demonstration is shown here in a test fixture. The primary mirror is four inches in diameter.

Cyber Security and Information Sciences

Laboratory researchers designed, developed, and deployed cyber situational awareness systems at several DOD national and mission operations centers, including the US Cyber Command and US Pacific Command. These systems share a common net-centric architecture in which data feeds and analytic services are discoverable, extensible, and composable. Feedback from operational use is driving ongoing development of new analytical and visualization tools.

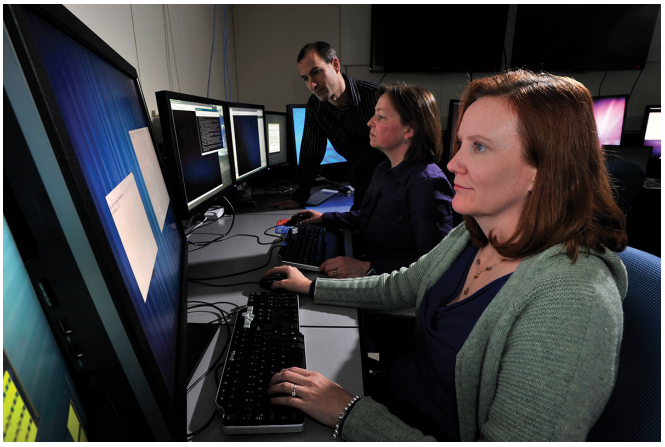

Figure 6. In the Lincoln Research Network Operations Center, researchers analyze results from a next-generation, prototype, spear-phishing, email detection system.

The Laboratory established the Lincoln Research Network Operations Center (LRNOC) to develop prototype cyber analysis tools by processing the Laboratory's own operational network traffic, security system alerts, information technology system logs, and configuration data. The LRNOC serves as a test bed for exploring and evaluating new techniques prior to prototype deployment on DOD networks.

Development of the Lincoln Adaptable Real-time Information Assurance Testbed (LARIAT) software suite continued. LARIAT is used to configure, command, and control large-scale experiments on cyber ranges, and has been deployed to dozens of DOD cyber ranges nationwide. The Laboratory worked on enhancing and deploying LARIAT components, including high-fidelity hardware-based cyber sensors, low-artifact traffic actuators, and autonomous Web 2.0 traffic generation.

The development of effective, dynamic, cryptographic key management techniques for small tactical systems continued. Laboratory researchers published a key management architecture for small unmanned aircraft systems and then worked with government and commercial organizations to establish elements of this architecture as a standard for widespread use.

In its computing and analytics work, the Laboratory developed algorithms and software tools for analyzing extremely large unstructured intelligence datasets. These tools have proven effective at automated data mining and analysis, and were deployed on remote, data-intensive computing centers. Research into statistical inference on very large graphs has begun to show promising results for real-world problems in ISR and cyber security. Techniques to detect anomalies in the topology of a community within a large network were developed and effectively demonstrated.

Intelligence, Surveillance, and Reconnaisance Systems and Technology

In 2012, Lincoln Laboratory deployed three systems for operational testing:

- Multi-aperture Sparse Imager Video System—an 880 Mpixel, color, airborne sensor
- Wide-area Infrared System for Persistent 360° Surveillance—a 100 Mpixel, infrared, ground-based sensor for base protection
- Imaging System for Immersive Surveillance—a 240 Mpixel, color, ground-based optical sensor for critical infrastructure protection

Common among these systems are the processing and exploitation tools that provide stitching, compression, geostabilization, target tracking, multi-intelligence fusion, and visualization.

The Laboratory developed a next-generation, three-dimensional imaging laser radar (ladar) system for the US Southern Command. This system is optimized for finding man-made structures under dense foliage canopy with area collection rates significantly higher than the rates of any existing ladar system. After system demonstrations this year, the sensor will undergo operational testing.

Two technologies developed in this mission area were awarded 2013 R&D 100 Awards: the photoacoustic sensing of explosives sensor and the structured knowledge space software system.

Improved maritime surveillance radar signal processing techniques were developed and demonstrated for several target classes. These techniques were assessed with substantial experimental data and will likely be transferred to current and future maritime radar systems. Passive sonar detection and ranging algorithms were developed to improve submarine undersea situational awareness. These algorithms help localize potential collision threats more accurately and are scheduled for operational fleet deployment following system and at-sea testing.

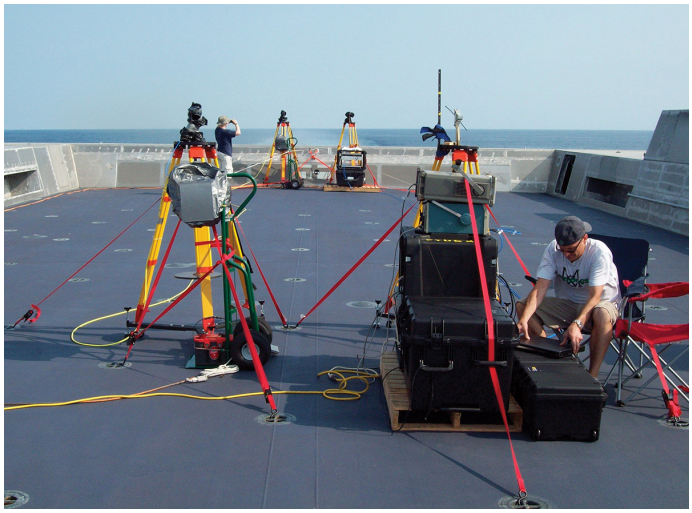

Figure 7. Staff members are deploying ship-based signal sources as part of the Laboratory's work evaluating surveillance radar performance in maritime environments.

Advanced Technology

Lincoln Laboratory researchers were the first to report the loading of an ion trap using atoms held in a remotely located magneto-optical trap (MOT). (Others have trapped ions from a MOT, but only from a collocated MOT, which has disadvantages associated with isotopic purity and surface contamination.) The remote approach results in a tenfold increase in loading times and will be important for large-scale experiments leading to a future quantum computer.

Record performance has been achieved with 1 μm wavelength slab-coupled optical waveguide lasers (SCOWL) and amplifiers (SCOWA). For SCOWAs operating at >1 W continuous wave (CW) single-mode output powers, electrical-to-optical efficiencies of up to 40% have been achieved. A SCOWA array comprising 47 individually seeded and addressable elements was packaged; raw power of up to 57 W CW (~1.2 W per SCOWA) was obtained. By using active phase control of each semiconductor amplifier, CW output of more than 50 W was obtained in a single output beam from such an array when combined. Single-mode SCOWL devices with output powers up to ~3 W CW have also been achieved.

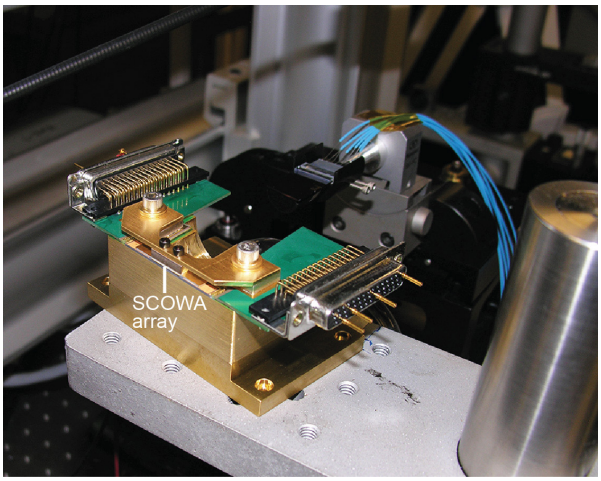

Figure 8. The 57 W, 1 μm wavelength, laser module comprises 47 individually addressable SCOWAs in a 5 mm long single-pass cavity.

The Laboratory offered access to ultra-low-power (ULP), fully depleted silicon-on-insulator, complementary metal-oxide-semiconductor technology across the Department of Defense community through a multi-project run sponsored by the Defense Advanced Research Projects Agency. Working with modern tools in the recently recapitalized Microelectronics Laboratory, Lincoln Laboratory delivered chips with 26 unique external ULP circuit designs submitted by university partners. Circuit designs and electrical results from contributors were presented at the IEEE Subthreshold Microelectronics Conference. This very successful conference, which featured more than 50 contributed talks and drew nearly 100 attendees, established Lincoln Laboratory as a leader in the emerging field of subthreshold microelectronics.

Homeland Protection

The field-deployable accelerated nuclear DNA equipment program delivered five prototype units for transition to the Departments of Defense, Justice, and Homeland Security. Through industry participation (by Network Biosystems), a six-channel prototype now automatically produces DNA profiles within 90 minutes. Lincoln Laboratory also developed collection techniques and a secure privacy-preserving framework for processing, storage, and analysis.

The Laboratory is working with the US Army Research Institute of Environmental Medicine to develop advanced physiological monitoring sensors, signal processing algorithms, and open architectures that will reduce heat casualties among service members. Field tests were conducted with the 22nd Chemical Battalion to assess thermal strain while personnel were wearing protective gear.

Under the sponsorship of the DHS Science and Technology Directorate, the Laboratory developed a mobile trace chemical collection and detection system for maritime cargo security. The system is being used to assess detection technologies and collect phenomenology data in operational port environments.

Figure 9. US Army Lieutenant Colonel Scott Jackson, a participant in the Laboratory's Military Fellows Program, loads DNA samples for processing in the accelerated nuclear DNA equipment prototype instrument. The microfluidic-based system is designed to be operated by technicians in expeditionary laboratory facilities to enable rapid, accurate human identification.

Lincoln Laboratory is advancing videoanalytics technology for performing attribute-based searches and for tracking suspects across arrays of conventional security cameras. The domain includes wide-area airborne and ground-based camera surveillance of locations and vehicles in and around buildings, ports, and waterways.

Tactical Systems

The Laboratory initiated the prototyping of four Air Force quick-reaction capabilities, fielding new intelligence, surveillance, and reconnaissance capabilities developed at Lincoln Laboratory.

The Laboratory developed and supported quick-reaction counterterrorism capabilities, including novel ground-penetrating radar, a unique robot-mounted sensor system, and two innovative airborne sensors developed as elements of a fielded, multi-intelligence ISR capability.

Assessment of digital radio frequency memory-based electronic attack impacts on air-to-air weapon systems continued. Systems analysis, advanced surrogate development, and hardware-in-the-loop and flight-testing enabled US electronic protection system improvements, and informed DOD's leadership decision making on future investments.

Figure 10. Lincoln Laboratory is developing a novel ground-penetrating radar capability to be used by combat engineers. An initial prototype has been integrated onto an Army Husky vehicle.

Air Traffic Control

Lincoln Laboratory plays a key role for the FAA in developing the next-generation airborne collision avoidance system, ACAS X. Research efforts showed that the ACAS X alerting logic will reduce the frequency of nuisance alerts by 50% while improving safety over the current Traffic Alert and Collision Avoidance System. As a result, the FAA has formalized the ACAS X program. The Laboratory's efforts in 2012 focused on preparing for flight trial with a hardware prototype expected in 2013.

Ten active array panels were fabricated, integrated, and tested to demonstrate affordable phased-array radar technology for meeting next-generation FAA weather and noncooperative target surveillance requirements. In addition, the Laboratory is performing an analysis to clarify applications and requirements for primary radars in the future national airspace system—for example, in sense-and-avoid systems for unmanned aerial systems.

The Tower Flight Data Manager (TFDM) is a first-of-its-kind, integrated, air traffic control automation system that provides situation awareness and decision support functions for managing and improving the safety and efficiency of airport operations. The Laboratory focused this year on an in-depth analysis of operational efficiency improvements that will be realized when TFDM is employed.

Figure 11. The next-generation airborne collision avoidance system, ACAS X, initial hardware prototype has undergone bench testing.

Engineering

The laboratory developed a mobile system that tests air in cargo containers for chemical agents. The system employs a robotic arm for sealing an airflow plenum against the container vent. Two truck-mounted systems were built for testing at various cargo facilities, and the test data will be used to evaluate the system's future use.

In a rapid prototyping effort, Lincoln Laboratory developed a sprayer system for use by U.S. Army and National Guard civil support teams that are responding to chemical-agent attacks. The system was built with commercial parts and in close coordination with future users. The system met aggressive weight and cost goals and is currently under consideration for transition to an industrial partner.

Completion of the shipboard mechanical installation of all components of the X-band Transportable Radar System included the assessment and correction of the antenna balance, fabrication and installation of a new antenna bull gear, and an upgrade of system cooling loops. Following this work, the system participated in its first mission.

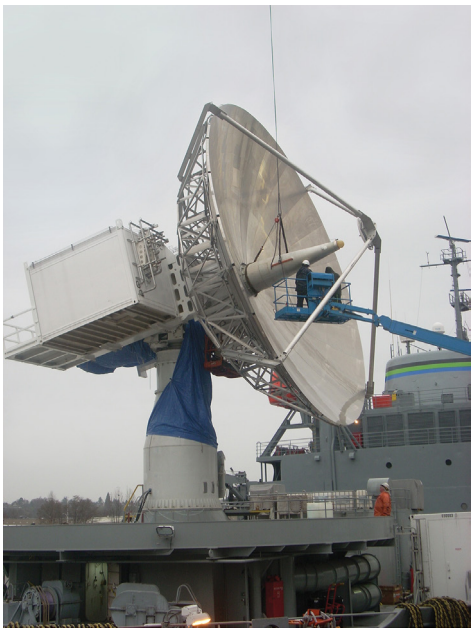

Figure 12. Lincoln Laboratory completed the feed installation for the X-band Transportable Radar, a large-scale, ship-based radio frequency system.

Technology Transfer and Knowledge Exchange

The culmination of many of Lincoln Laboratory's development projects is the transfer of technology to government agencies, industry, or academia. The mechanisms for this transfer include delivery of hardware, software, algorithms, or advanced architecture concepts to government contractors under the auspices of a government sponsor; small-business technology transfer projects, which are joint research partnerships with small businesses; and cooperative research and development agreements, which are privately funded by businesses to transfer the laboratory's technology.

Technology transfer activities over the past year include the following:

- A new system to aid foreign language learners in developing pronunciation skills was delivered to the Defense Language Institute. The system applies speech recognition technology to produce online assessments of pronunciation so that students can interactively improve their pronunciation.
- A high-data-rate waveform for wideband, transponded satellite communications was demonstrated and delivered to more than 15 industry and government organizations.
- The prototype software for a radio-to-router common virtual multipoint interface for the Linux operating system was released for public access as open-source code. The interface will simplify interoperability among heterogeneous radios.
- Lincoln Laboratory transferred a malware triage system to sponsor organizations. Cyber range technology was provided to government and industry cyber ranges.
- Core components of the TFDM were transferred to an industry contractor for deployment to Dulles International Airport, Washington, DC.
- The Corridor Integrated Weather System Data Distribution Service provides high-quality current and 0–2 hour weather forecast data for airlines and FAA traffic flow management personnel. The service became operational in 2012 and is now integrated into the FAA's traffic flow management automation for use in air traffic control facilities across the United States.
- In support of the national need for wide-area motion imaging, Lincoln Laboratory continued to support the Constant Hawk (Army) and Gorgon Stare (Air Force) programs. Onboard processing software improvements, ground station upgrades, and viewer and exploitation tool enhancements were delivered to operational users to improve the efficacy of these systems.
- The Airborne Ladar Imaging Research Testbed system developed by the laboratory continues its operational use on board a government-furnished aircraft. The Laboratory provides support to sensor operation, onboard processing, and image data exploitation tools.
- Between 1 July 2012 and 30 June 2013, MIT was awarded 24 US patents for technologies developed by Lincoln Laboratory researchers.

2013 R&D 100 Awards

Two Lincoln Laboratory technologies were named 2013 recipients of R&D 100 Awards. Recipients are selected annually by *R&D Magazine* as the 100 most technologically significant innovations introduced during the previous year. The winning technologies listed below represent work in two distinct areas of research:

- Photoacoustic Sensing of Explosives Sensor—a highly portable system that detects trace explosives' residue deposited on common surfaces
- Structured Knowledge Space—a software system that facilitates search and analysis of the vast collection of intelligence reports generated by multiple agencies

Technical Workshops

The dissemination of information to the government, academia, and industry is a principal activity of Lincoln Laboratory's technical mission and is achieved through annual workshops and seminars that bring together members of technical and defense communities. These events foster a dialogue that enhances technology development and provides direction for future research. This year, following federal budget sequestration, the duration of each workshop was shortened and sessions were held with reduced on-site attendance, using video-teleconferencing whenever possible. The following workshops were held this year:

- Mechanical Engineering Technology Symposium
- Subthreshold Microelectronics Conference
- Intelligence, Surveillance, and Reconnaissance Systems and Technology Workshop
- Software Engineering Symposium
- Space Control Conference
- Air Vehicle Survivability Workshop
- Ballistic Missile Defense Workshop
- Lincoln Laboratory Communications Conference
- Cyber and Netcentric Workshop

Publications

Knowledge dissemination is also achieved through the diverse venues in which Lincoln Laboratory researchers publish. Technical staff members publish articles in peer-reviewed journals and present at national technical conferences such as the IEEE Military Communications Conference and the International Conference on Acoustics, Speech, and Signal Processing. Between July 1, 2012, and June 30, 2013, Lincoln Laboratory staff published 107 papers in proceedings from such conferences and 89 articles in technical journals.

In addition, the laboratory publishes the *Lincoln Laboratory Journal*, which contains comprehensive articles on current major research and journalistic pieces highlighting novel projects. The journal supplies sponsor agencies with technical reports, some of which are available through the DOD's Defense Technical Information Center.

Military Fellows Program

Lincoln Laboratory awards fellowships to support the educational pursuits of active-duty military officers who are fulfilling requirements for the US military's senior service schools or for the Army's Training with Industry Program, or who are working toward advanced degrees. This program helps the Laboratory establish cooperative relationships with military officers and allows researchers to gain constructive insight from the front-line experiences of the officers who are assigned to technical programs within the lab. Currently, 17 officers from all the services are working at the Laboratory under fellowships.

University Student Programs

Lincoln Laboratory offers a variety of research and internship opportunities to university students. Candidates in MIT's 6-A Master of Engineering Thesis Program may spend two summers as paid interns, participating in projects related to their fields. Then the students work as research assistants while developing their theses under the supervision of both Laboratory engineers and MIT faculty. In 2012, four students took advantage of this program. The Laboratory also employs other research assistants from across MIT's engineering departments. Currently, 42 MIT students are employed as research assistants. In addition, usually during the summer, the laboratory employs students participating in MIT's Undergraduate Research Opportunities and Undergraduate Practice Opportunities programs; in summer 2012, 16 students worked under these programs.

Each summer, the laboratory hires undergraduate and graduate students from top universities as interns in technical groups. In summer 2012, 74 undergraduates and 89 graduate students from 69 different schools worked at the laboratory. Throughout the year, cooperative education students from area colleges, such as Northeastern University and Wentworth Institute, work at Lincoln Laboratory. During the 2013 spring semester, 46 cooperative education students from area schools were employed in technical divisions and service departments.

Through an ongoing partnership with Worcester Polytechnic Institute (WPI), students work at the Laboratory to fulfill requirements for their senior thesis projects; in 2012, 12 WPI students were accepted as interns.

Collaboration with MIT Campus

Initiatives supported by both MIT and Lincoln Laboratory promote research collaborations, foster knowledge exchange, and enhance professional development. Below are some of the cooperative initiatives that strengthen research at both institutions.

Integrated Photonics Initiative

A unique partnership between Lincoln Laboratory and the MIT campus is the Integrated Photonics Initiative, a multiyear, Lincoln Laboratory–funded effort that enhances the research experience for PhD candidates working on integrated photonics devices and subsystems for potential insertion into advanced communications and sensor systems.

The initiative has been developing new devices and subsystems to advance the field of coherent optics, which are of increasing interest for use in applications such as optical communications, laser radar, and microwave photonics.

Beaver Works

Lincoln Laboratory is engaged in ongoing collaborations with departments and centers at MIT to provide project-based educational experiences to undergraduate and graduate engineering students. Capstone projects afford students a yearlong involvement in the research, design, fabrication, and test phases of developing a prototype system. The program leverages the technical staff's expertise and the Laboratory's prototyping resources to scale up campus-led projects, and it draws on campus expertise to develop new Lincoln Laboratory–led projects. The initiative has been dubbed "Beaver Works," in reference to the MIT mascot and the term "Skunk Works," an industry name that came to denote an assignment-specific group working on a specialized project.

The Beaver Works program offers unique benefits:

- MIT faculty and students gain awareness of national security problems and strengthen their relationship with DOD.
- The expansion of project-related education enhances students' experiences and MIT's reputation as a cutting-edge institution.
- By leveraging MIT and Lincoln Laboratory resources, the Beaver Works enables both institutions to make a strong impact on a broad set of problems in service to the nation.
- Lincoln Laboratory gains increased access to campus technical expertise, exposure to the entrepreneurial campus culture, and the opportunity to recruit top graduates.
- DOD development programs can benefit from a stronger coupling with MIT research.

This year, there were two capstone projects on the development of unmanned aerial vehicles (UAVs) and one project on developing a subsystem for an autonomous undersea vehicle. Beaver Works research projects included three projects on cyber security, one on biomimetics, two on small UAVs, and one on transportation.

A Beaver Works center is planned to open in fall 2013. The center is a joint facility chartered by MIT's School of Engineering and Lincoln Laboratory, and will be operated by Lincoln Laboratory. The 5,000- square-foot center, located in Technology Square in Cambridge, MA, will be open to all MIT students, faculty, and collaborators. With spaces designed for diverse activities—building prototype systems, conducting demonstrations, and brainstorming solutions—the center will become a resource for innovation, collaboration, and hands-on development.

Research Collaborations

There are multiple mechanisms for direct support of and collaboration with MIT campus researchers. Each year, Lincoln Laboratory spends between 8% and 10% of its internal research and development funding on campus through these mechanisms. Campus collaborations are three-year renewable grants to MIT faculty and research staff working on topics of relevance to Lincoln Laboratory's primary mission areas. These grants are intended to foster the development of long-term working relationships between Lincoln Laboratory staff and MIT researchers. In addition, the Advanced Concepts Committee provides short-duration grants to MIT faculty and staff for focused research in basic and applied science and technology areas of potential interest to the Laboratory. Collaborative mission-focused projects are also supported directly from this funding source as well from external program sponsors in DOD, the Department of Energy, NASA, and other government agencies.

Infrastructure

Facility

The Capital Projects Office is continuing the development of a long-range plan for adding modern laboratory spaces and alleviating office overcrowding. Lincoln Laboratory is exploring options to move staff from offices in multiple departments into leased, refurbished office space on Hanscom Air Force Base property. Another goal is to add a new, modern facility with purpose-built spaces for fabrication, integration, and rapid prototyping as well as electronics laboratories and clean rooms. The laboratory has drafted a plan to finance the construction of a new building and is awaiting DOD and congressional approval of the plan.

The Facility Services Department manages Lincoln Laboratory's capital renewal program, which encompasses two main pieces: annual capital investment projects and the deferred maintenance program (DMP). "Deferred maintenance" refers to building and systems maintenance that was postponed because of limited resources or funding.

In the category of annual capital investment projects, plans are under way for a new heating, ventilation, and air conditioning (HVAC) air handler for a cleanroom in Building I; the system is scheduled for deployment in fiscal year 2014. Also in the planning stage is the design for electrical and mechanical infrastructure updates to support the proposed new laboratory building.

The Laboratory initiated a formal DMP in 2009 to direct critical updates to the facility. On the basis of a comprehensive facility condition evaluation, the department allocates a yearly budget to the DMP. Total program expenses to date equal $35 million. Deferred maintenance projects are continually reprioritized on the basis of their effect on or critical nature relative to the Laboratory's mission. Project categories include life safety, building envelope repairs, HVAC and systems upgrades, electrical improvements, aesthetics, and other renewal needs. The department monitors the program's progress through reiterative facility condition assessments.

A few of the major DMP projects initiated in 2013 include the L-Infill façade and roof replacement, lower roof and exhaust fan replacements for the Microelectronics Laboratory, and the campus emergency-generator replacement, which is a multiphase, multiyear initiative. A major in-house design effort was completed, with construction to start in fiscal year 2014.

Services

Lincoln Laboratory continues to augment support services. Some of the improvements are highlighted below.

In 2013, the Information Services Department (ISD) released new services for secure internal web conferencing and secure file transfer with external sponsor organizations. The internal web conferencing service allows both sharing of presentations and audio and video broadcasting. A reusable framework for online support of conferences and events was also developed, enabling rapid support for the many activities hosted by the laboratory.

Major updates were made to the local network infrastructure and to the VoIP telephone platform. New asset management and compliance reporting tools were deployed, as well as a new information technology service management ticketing system for ISD and other internal groups. Large volumes of printed information were digitized for online access and a new geospatial data service was created.

ISD, in collaboration with the Security Services Department, continued major cyber security improvements, including a new vulnerability assessment program and increased layered network security.

The Financial Services Department focused on financial planning and scenario modeling to address the uncertainty of the impact of sequestration. As part of the Business Process Improvement (BPI) initiative coordinated by the Financial Services Department and ISD, a new anticipated funding module was implemented; this module allows the research divisions to plan funding by month and has allowed the department to more centrally track and report on how funding is coming in against the plan. Work started on the next phase of BPI, which will improve the planning of monthly spending against program funds. In addition, a new suite of business software tools will be introduced to allow for dashboard reporting, web queries, and analytics. Another project under BPI, the procurement-to-pay work initiative, will include system and process updates beginning with procurement and continuing through to vendor payment.

The Security Services Department led the effort that earned Lincoln Laboratory its seventh consecutive “superior” security rating from the US Air Force’s 66th Air Base Group Information Protection Office. In calendar year 2012, 36 successful government security-related reviews were conducted by multiple government agencies.

The Security Services Department strengthened its program at the laboratory by accomplishing the following strategic goals:

- Conducted the Blue Ribbon Security Review III; the review team's findings stated that the laboratory's current security posture is excellent
- Implemented new forensic analysis tools that improve the protection of laboratory data on various media platforms, including CDs, USB devices, and personal media
- Streamlined processes and increased connectivity across multiple DOD sponsor networks
- Expanded educational resources for the Laboratory's information systems security officers
- Strengthened the Laboratory's Insider Threat Program through the integration of the Investigations/Counterintelligence Office and Personnel Security Services Center
- Enhanced physical security controls for approximately 90 secure areas; the new locking systems enable improved monitoring of secure areas
- Automated numerous processes to provide customers with timely online tracking of their requests for department services, such as initiating security clearances or processing program access requests

The Contracting Services Department supported the federally funded research at Lincoln Laboratory by issuing approximately 52,000 procurement transactions with a value of $437 million in 2012. In addition, the US Air Force administrative contracting officer approved the Laboratory's purchasing system after a comprehensive contractors' purchasing system review was conducted by the Defense Contract Management Agency.

Other department achievements include the successful implementation and release of the Laboratory Code of Conduct and Laboratory Ethics Hotline. DOD now requires organizations receiving DOD funding to establish an organizational code of conduct consistent with federal guidelines. This code ensures that Lincoln Laboratory will remain compliant with its prime contract and the updated policies of the federal acquisition regulations.

Lincoln Laboratory was awarded the US Small Business Administration's 2013 Dwight D. Eisenhower Award for Excellence–Research and Development. This award recognizes large prime contractors that demonstrate exemplary commitment to using small businesses as subcontractors and suppliers. The award is testament to the Laboratory's Small Business Office's continuing efforts to expand its reach to small businesses in the region.

Community Outreach

Education

Recognizing the importance of preparing young people for careers in science, technology, engineering, and mathematics (STEM), Lincoln Laboratory Community Outreach (LLCO) administers a significant program of STEM activities. Highlights of 2012–2013 educational outreach activities are described below.

In 2013, the Laboratory expanded its two-week residential program for high school students. In this second year of the program, 18 soon-to-be seniors from across the country participated in the Lincoln Laboratory Radar Introduction for Student Engineers program. This summer workshop offers instructional sessions on the basics of radar systems and radar imaging; workshops for building radar systems that can perform range-Doppler imaging; and hands-on demonstrations using the radars built in the workshops. During the two weeks, students are housed in a dormitory at MIT and attend sessions on campus to learn more about the college application and financial aid processes.

Figure 13. The students who participated in the 2013 Lincoln Laboratory Radar Introduction for Student Engineers summer workshop are seen here with the Laboratory's director, Dr. Eric Evans (far left), and the instructors and teaching assistants for the two-week engineering immersion program.

Lincoln Laboratory sponsored two teams in the 2012 Team America Rocketry Challenge, a national program established in 2002 to foster student interest in science and engineering through competitions to build rockets that accomplish prescribed tasks. The challenge program was a new venture for laboratory outreach volunteers. Although the teams did not earn a place at the national finals, their mentors commended the students' ability to apply engineering principles to make improvements to their design during the competition itself.

Lincoln Laboratory's robotics initiative, Robotics Outreach at Lincoln Laboratory (ROLL), continues to mentor teams in the For Inspiration and Recognition of Science and Technology (FIRST) competitions. The MightyBots team of high-school students won the Think Award and the Innovate Award at separate regional tournaments, and won the Promote Award at the Massachusetts Championship tournament. Laboratory technical staff members mentor 11 teams in the FIRST division for students in grades 4 to 8. In addition, ROLL volunteers assist FIRST teams from schools in Boston, Waltham, Lexington, Weston, and Shrewsbury, MA, by providing technical guidance and staging scrimmages.

A team of high-school students mentored by Laboratory staff participated in the national CyberPatriot competition in which teams are challenged to respond to simulated cyberattacks. The six-member Donut Hack Us team was named Open Division National Finalists.

Science on Saturday, the Lincoln Laobratory's first STEM program, is still drawing 700 K–12 students, parents, and teachers to each of the five annual on-site science demonstrations given by technical staff members during the academic year.

Lincoln Laboratory is continuing its partnership with the MIT Department of Engineering's Office of Engineering Outreach Programs (OEOP). The Laboratory sponsors students in each of four OEOP programs, provides tours of Lincoln Laboratory's unique facilities to the student groups, and offers courses or presentations given by members of the technical staff.

The Laboratory's other established educational outreach programs—classroom presentations at local schools by technical staff members, internships for six high-school students, and the Ceres Connection that names asteroids in honor of science fair winners—are all continuing.

Community Service

The Laboratory's community service program is strong. The LLCO helps increase Laboratory employees' awareness of events sponsored by charitable organizations. The Memory Walk for the Alzheimer's Association raised $24,750 to provide services to patients in Massachusetts and New Hampshire. The LLCO again facilitated participation in Bike and Hike, the Berkshires event that raises funds for the Multiple Sclerosis Society; $10,635 was raised by the team. The bicyclists also participated in the Minuteman Ride "bike-athon," raising another $4,000 for research into multiple sclerosis. The annual holiday clothing, food, and gift drives brought in warm coats, food, and gift items. Approximately 300 toys were donated by Lincoln Laboratory employees to the MIT Federal Credit Union's annual drive for Toys for Tots. The Lincoln Laboratory Technical Women's Network helped Habitat for Humanity volunteers renovate a home in Lowell, MA, intended for sale at an affordable price, and members of the Hispanic/Latino Network volunteered at the Boston Food Pantry. Support Our Troops, one of the LLCO's first community giving programs, is an ongoing campaign to collect and mail food, toiletries, and books for US soldiers overseas; this year, program volunteers sent approximately 250 packages to troops overseas.

Summary

Although the Laboratory's diverse sponsor base has been affected by sequestration, the demand for Lincoln Laboratory's research and prototype development remains strong. Current programs extend from fundamental investigations to developmental engineering to operational testing of prototype systems. The Laboratory's range of programs continues to be well balanced with system development in the core missions, innovative research projects, and large-scale programs.

Emerging national concerns are leading to opportunities for research and development in areas such as cyber security, autonomous systems, quantum information sciences, and biomedical technologies. The highly multidisciplinary work in the Advanced Technology Division leverages solid-state electronic and electro-optical technologies, innovative chemistry, and advanced radio frequency technology to develop advances in subsystem and component design. The division is also investigating novel engineered materials and new methods in microelectronics.

Ongoing improvements to administration and infrastructure help sustain Lincoln Laboratory's ability to achieve technical excellence. Charitable activities are providing needed resources to local communities and organizations, and the educational outreach program is expanding in both its depth and its reach to students in underserved communities. In conclusion, Lincoln Laboratory is well positioned to take on the challenges of its mission of "technology in support of national security."

Eric D. Evans
Director