

## Lincoln Laboratory

Lincoln Laboratory is a Department of Defense (DoD) federally funded research and development center operated by the Massachusetts Institute of Technology. Under a prime contract with the 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 relevancy 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 health care needs and enhance soldier fitness and resilience. Research into novel and engineered materials is focused on low-loss and wide-bandwidth metamaterials for use in compact, high-performance antennas and on graphene-plasmonic hybrids for the protection of focal planes from intense laser pulses. Rapid prototyping efforts continue to be important across various mission areas.

For the fiscal year July 1, 2013, to June 30, 2014, Lincoln Laboratory received approximately \$929 million to support the efforts of approximately 1,720 professional technical staff and 1,460 technical and administrative support personnel; outside procurement will exceed \$345 million. While 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 Oceanic and Atmospheric Administration (NOAA). In addition, Lincoln Laboratory 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 a 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 (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, Mission Assurance, and Program Support Office, as a primary advisor, enable cross-divisional research teams to coordinate and manage the technical and programmatic challenges of large-scale developments.

### **Changes to Leadership**

#### ***Director's Office***

Dr. Steven R. Bussolari transitioned to Lincoln Laboratory's Washington, DC, site to serve as the technical advisor to the Air Force Rapid Capabilities Office.

#### ***Air and Missile Defense Technology Division***

Dr. Justin J. Brooke was appointed head of the Air and Missile Defense Technology Division. Formerly, he was the assistant head of the Intelligence, Surveillance, and Reconnaissance and Tactical Systems Division. Dr. Katherine A. Rink was appointed assistant head of the division; she previously served as the leader of the division's Advanced Concepts and Technologies Group.

#### ***MIT Lincoln Laboratory Beaver Works Center***

Dr. Robert T-I. Shin, head of the Intelligence, Surveillance, and Reconnaissance and Tactical Systems Division, was named director of the MIT Lincoln Laboratory Beaver Works Center, a joint venture of the Laboratory and the MIT School of Engineering.

### **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 Figure 2. The total number of

Laboratory employees is 3,685, with 1,721 professional technical staff, 1,463 support staff (including technical support personnel), and 501 subcontractors.

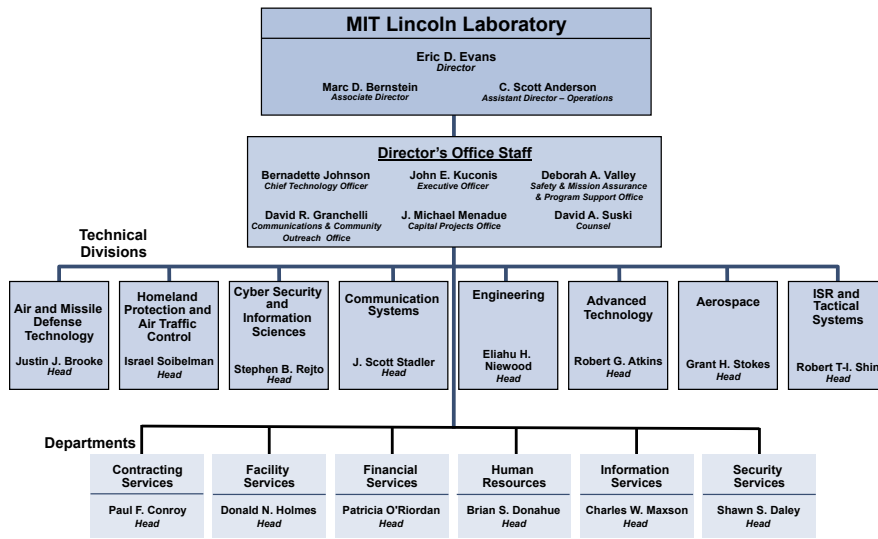


Figure 1. MIT Lincoln Laboratory organizational structure as of July 1, 2014.

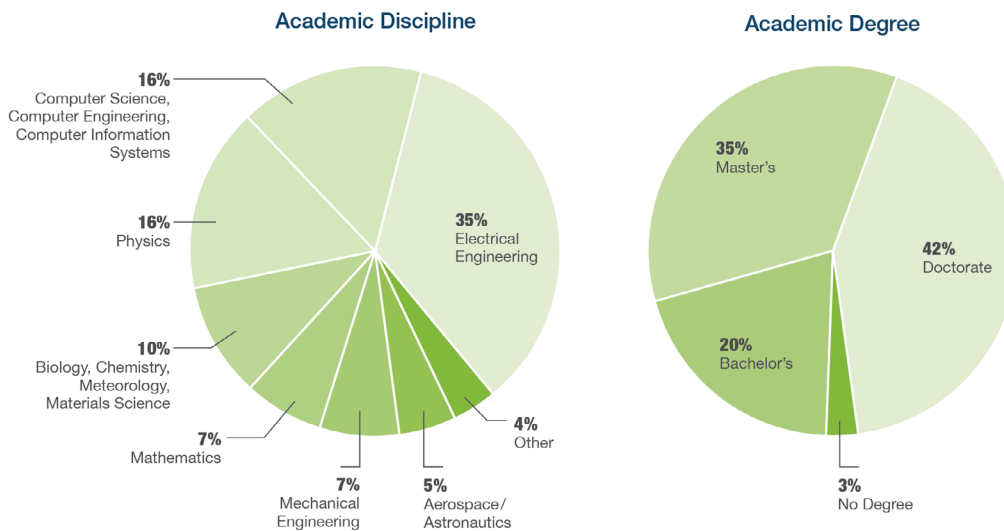


Figure 2. Composition of professional technical staff at MIT Lincoln Laboratory by (a) academic discipline and (b) academic degree.

### 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. Eric D. Evans was appointed by the Office of the Secretary of Defense as vice chair of the Defense Science Board (DSB). As a member of the DSB since 2010, he has served on several task forces and co-led studies on improvised explosive devices (IEDs) and on cyber security and reliability in a digital cloud. Dr. Evans was also presented the 2014 Distinguished Award for Excellence in Engineering by the Armed Forces Communications and Electronics Association.

- Dr. Robert T-I. Shin received the Irwin Sizer Award for the Most Significant Improvement to MIT Education for his vision and leadership in developing Lincoln Laboratory's Beaver Works Center, which is supporting project-based learning and innovation through collaborative research initiatives.
- Dr. Mordechai Rothschild won the 2014 SPIE Frits Zernike Award for Microlithography for his significant contributions to the advancement of lithography through the exploration and demonstration of deep-ultraviolet and vacuum-ultraviolet materials, lasers, and systems.
- Dr. Jeremy Kepner and Dr. Roderick R. Kunz received 2013 Lincoln Laboratory Technical Excellence Awards. Dr. Kepner was recognized for "his leadership and vision in bringing supercomputing to Lincoln Laboratory through the establishment of LLGrid; his pivotal role in open systems for embedded computing; his creativity in developing a novel database management language and schema; and his contributions to the field of graph analytics," while Dr. Kunz was cited for "his outstanding technical contributions to the team that developed the 193-nm lithography process for integrated circuit device fabrication, and for subsequent advancements in lithography, such as the world's first photolithography exposure tool and procedures for improving the durability of 193-nm lenses."
- 2013 MIT Lincoln Laboratory Early Career Technical Achievement Awards were presented to Dr. Brooke E. Shrader for her work on network protocols for communications systems and Scott Van Broekhoven for his work on advanced energy systems and miniature unmanned aerial vehicles.
- Dr. Andrew L. Puryear, MIT professor Jeffrey H. Shapiro, and Dr. Ronald R. Parenti won the 2013 MIT Lincoln Laboratory Best Paper Award for "Reciprocity-Enhanced Optical Communication Through Atmospheric Turbulence— Part I: Reciprocity Proofs and Far-Field Power Transfer Optimization" and "Part II: Communication Architectures and Performance." The papers were published in December 2012 and August 2013 in the *IEEE/OSA Journal of Optical Communications and Networking*.
- Dr. Michael W. Kelly, Dr. Daniel L. Mooney, Curtis B. Colonero, Dr. Robert Berger, and Lawrence M. Candell received the 2013 MIT Lincoln Laboratory Best Invention Award for their "digital readout method and apparatus." A patent for this technology was issued in May 2012.
- Joseph S. Ciampi and William H. Kindred won 2014 MIT Lincoln Laboratory Administrative Excellence Awards.
- Kenneth L. Burkett and Cynthia J. Wallace received 2014 MIT Lincoln Laboratory Support Excellence Awards.
- Dr. Keith B. Doyle was elected a 2014 fellow of SPIE for achievements in advancing optomechanical engineering and integrated modeling.

- 2014 MIT Excellence Awards were presented to J. Darby Mitchell in the Bringing Out the Best category, Michael R. Doiron and Albert L. Traniello in the Serving the Client category, Stefan C. Wolpert in the Unsung Hero category, and the Virtual Conference Development Support Team—Laura Bloom, Daniel R. DiPrima, Matthew C. Ellis, Justin M. Lacroix, Steven M. Schoeffler, Tom H. Schultz, Kevin J. Van Steensel, and Kevin J. Zablonksi—also in the Unsung Hero category.
- Michael L. Stern, a Lincoln Scholar pursuing an MEng degree at MIT, was presented the MIT Mechanical Engineering Department's Carl G. Sontheimer Prize, which recognizes creativity and innovation in design.

### **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/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. During the past year, 26 staff members were enrolled in the Lincoln Scholars program.

The Graduate Education Committee also coordinates distance learning programs: master's degree programs in information technology (IT) 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. During the past year, three people were enrolled in the Carnegie Mellon program and two in the Penn State program.

The technical education program offers semester-length courses taught by Lincoln Laboratory technical staff or by outside experts, often professors from MIT. The 2013–2014 schedule included the following courses:

- Decision Making Under Uncertainty
- Digital Signal Processing 1–3 (Signals and Systems; Discrete Fourier Transform, Digital Filters, and Filter Banks; and Statistical Signal Processing)
- Electromagnetics and Antennas
- Electronic Warfare
- Introduction to Cyber Security
- Introduction to Radar
- Rapid Robotics: Autonomous Systems with Open-Source Software
- Semiconductor Device Physics and Technology

- Systems Engineering
- Theory and Method of Graph Analysis

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, Photoshop, etc.), programming, and technical software (MATLAB, Simulink, VMware, etc.) is offered on-site throughout the year.

- The Technology Office coordinates an extensive program of seminars presented at the 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 thrusts. Highlights of the 2013–2014 seminar program include the following: "Sensitive Robotics," professor Eduardo Torres-Jara, Worcester Polytechnic Institute
- "A Tale for Our Times: Climate Change and the Reasons for Climate Gridlock," professor Susan Solomon, MIT Department of Earth, Atmospheric and Planetary Sciences
- "Bioinspired Materials: Hierarchies from Nano to Macro and Analogies Between Materials and Music," professor Markus Buehler, MIT Department of Civil and Environmental Engineering
- "Optical Coherence Tomography—MIT Lincoln Laboratory History, Current Status, and Future Opportunities," Dr. Eric Swanson, director of Acacia Communications
- "New Synthetic Tools for the Fabrication of Functional Metal/Organic Interfaces and Networks," professor Jeremiah Johnson, MIT Department of Chemistry
- "Complex Systems Science and the Challenges of Engineering for and of a Complex World," Yaneer Bar-Yam, professor and president, New England Complex Systems Institute
- "Chasing the Echoes of the Big Bang with BICEP2," Dr. Randol Aikin, MIT Lincoln Laboratory
- "National Security Implications of Climate Change," Marc Levy, deputy director, Science Applications Division, Center for International Earth Science Information Network, Columbia University

### ***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 broader range of universities, programs in mentoring, employee resource groups such as the New

Employee Network, and flexible work options are contributing to the hiring and retaining of a more diverse workforce.

### ***Mentorship Programs***

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 their inception in 2011, 1,057 individuals have participated in these four programs; during the past year, 453 people were engaged in the programs as either mentees or mentors. These mentoring programs help enhance employees' professional development, help foster a welcoming environment, and contribute to the Laboratory's ability to retain a diverse workforce.

### ***Employee Resource Groups***

Employee resource groups at Lincoln Laboratory help create an inclusive environment through engagement in professional development activities, volunteer work with educational and charitable outreach programs, and provision of support to members of the Laboratory community. Currently, six resource groups are active: the Lincoln Employees' African American Network, the Out Professional Employee Network, the Lincoln Laboratory New Employee Network, the Lincoln Laboratory Technical Women's Network, the Lincoln Laboratory Hispanic and Latino Network, and the Lincoln Laboratory Veterans' Network.

The Lincoln Laboratory Hispanic and Latino Network received the MIT Martin Luther King Jr. Leadership Award for its outstanding service to MIT and the broader community, and the Out Professional Employee Network received the 2014 MIT John S.W. Kellett '47 Award for its commitment to creating a welcoming environment at MIT.

### ***Diversity Events***

On January 27, the Lincoln Employees' African American Network hosted the Laboratory's first annual Martin Luther King Jr. Breakfast at the Minuteman Commons Community Center on Hanscom Air Force Base. This event's theme, "Lead by Example," encouraged attendees to share in King's dream by working toward ensuring that laws enacted to guarantee equality are actually implemented. Former Radar Measurements Division head Wade M. Kornegay, the first African American division head at Lincoln Laboratory, offered his "lessons learned." Dr. Percy A. Pierre, vice president emeritus and professor of electrical and computer engineering at Michigan State University and the first African American to earn a doctorate degree in electrical engineering in the United States, spoke about the historical roots of the African American Civil Rights Movement and the still-current need for continued progress toward equality for all.

In November 2013, the Office of Diversity and Inclusion and the director's office cohosted the fourth annual Veterans' Appreciation Luncheon on Hanscom Air Force Base. General Mark A. Welsh III, US Air Force chief of staff, delivered the keynote address.



In March 2014, Jen DeLuca, executive director of Fisher House Boston, and two retired Air Force staff sergeants spoke at the Laboratory about the mission of Fisher House Boston, a foundation that donates “comfort homes” near major military and veteran medical centers so that military family members can be close to relatives being treated for illnesses or injuries.

### **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 2013–2014, the Laboratory worked on approximately 650 sponsored programs ranging from large-scale hardware projects to small seedling initiatives. Notable highlights for each mission area are listed below.

### **Advanced Technology**

In 2013, a significant milestone in the combining of fiber lasers was reached with the demonstration of record power with high beam quality and electrical efficiency.

A record optical power of 50 W in a diffraction-limited beam was achieved by coherently combining a 47-element array of 1.06  $\mu\text{m}$  wavelength slab-coupled optical waveguide (SCOW) amplifiers. The Laboratory also collaborated with Science Research Laboratory to demonstrate more than 200 W continuous power (uncombined) from 100-element dense SCOW laser arrays for use as high-brightness fiber-laser pumps.

An engineering development unit version of the Rapid Agent Aerosol Detector (RAAD) was completed. RAAD provides an upgrade to the Joint Biological Point Detection System, enabling bioaerosol triggering at lower false trigger rates and providing better maintainability than current state-of-the-art bioaerosol triggers.

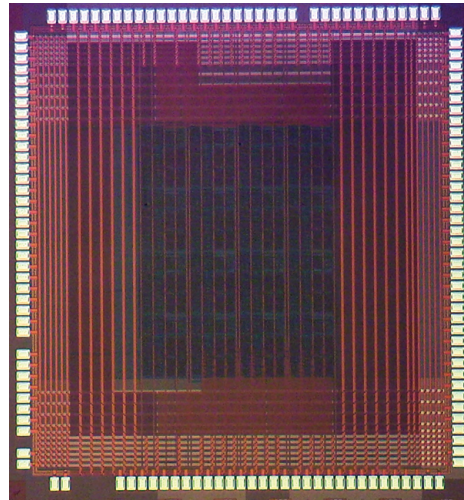
The Radio Frequency (RF) Enhanced Digital System on Chip program has developed a fully integrated system-on-chip design and submitted it for fabrication at a silicon foundry. The design achieves record receiver performance at a very small size, weight, and power.

Record coherence times were achieved in two-dimensional and three-dimensional transmon superconducting qubits for quantum computing applications. These devices used larger mode volumes and epitaxial materials to achieve these results.



An additional curved focal surface, consisting of back-illuminated charge-coupled-device imagers, is being prepared for use by the Space Surveillance Telescope program, developed by the Defense Advanced Research Projects Agency.

The Laboratory has applied ultra-low-power (ULP) complementary metal-oxide semiconductor technology to a ULP field-programmable gate array (FPGA). A small-scale demonstration FPGA is currently being fabricated in the Microelectronics Laboratory, and a larger array is being designed for fabrication later this year.



*Figure 3. The subthreshold field-programmable gate array test chip demonstrated a record low programming voltage (0.26V) by replacing static random-access memory with latches.*

In the area of heterogeneous integration of electronic-photonic components, the Laboratory, in collaboration with MIT, has completed the design of silicon photonic components and electronic circuits that will be three-dimensionally integrated via oxide bonding.

### **Air and Missile Defense Technology**

Lincoln Laboratory led the Missile Defense Agency's Counter-Countermeasure team. Activities focused on the development of mitigation techniques and algorithms effective against a broad spectrum of advanced ballistic missile defense countermeasures. Guidance was provided for the Integrated System-Level Discrimination effort.

The Missile Defense Agency Sensors Directorate fielded a debris mitigation real-time experiment, a sidecar built by the Laboratory, on the AN/TPY-2 forward-based radar during FTI-01 testing. This experiment provided an early test of near-term preintercept and postintercept debris mitigation algorithms. The sidecar was also employed for additional experimentation using the AN/TPY-2 and Ground-Based Radar Prototype radars in regional and strategic missile defense tests in 2013.

The Laboratory supports development of countermeasure concepts as part of the Ballistic Missile Defense System. The Laboratory has developed countermeasures to test counter-countermeasure techniques for the emerging system.



*Figure 4. The gimbaled slotted planar array in the Gimbaled Airborne Test Radar test bed collects coherent range-Doppler measurements to demonstrate and evaluate the performance of advanced radar tracking and discrimination performance algorithms. The team that developed this radar was honored with a Lincoln Laboratory Team Award in 2014.*

Key contributions were made to the planning, execution, and post-mission evaluation of the October 2012 FTI-01 and September 2013 FT0-01 events, the most complex integrated live-fire missile defense tests ever conducted. Activities in Lexington, MA; Huntsville, AL; and the Reagan Test Site (RTS) at Kwajalein spanned the entire test cycle and focused on the significant challenges to test success.

Several milestones were achieved under the RTS Improvement and Modernization Program. The Optics Modernization Program achieved initial operational capability (IOC) for two telescope systems, and the Real-Time Open Systems Architecture project reached IOCs with the Millimeter-Wave Radar, ARPA-Lincoln C-band Observables Radar (ALCOR), and MPS radars. The Real-Time Telemetry Open Systems and RTS Automation and Decision Support development projects also achieved important early milestones.

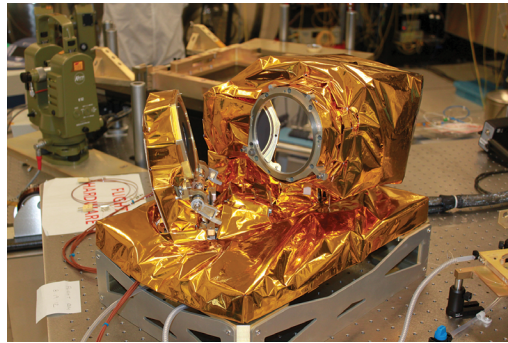
Work continued on a Future Naval Capabilities program, Integrated Active and Electronic Defense, that provides integrated hard-kill and soft-kill engagement scheduling for future shipboard combat systems. This project builds on a previous program and extends the coordination approach to the multiship force level.

The Laboratory's increased role in the development and assessment of over-the-horizon radar capabilities included the development and demonstration of new signal processing techniques to mitigate clutter and ionospheric propagation challenges, development and demonstration of a next generation of fully digital array architectures, and investigation of the impact of various forms of interference on system performance.

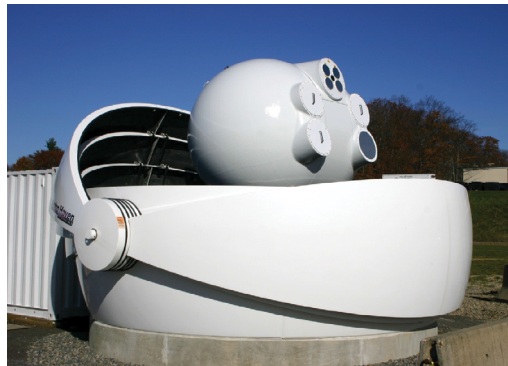
### **Communication Systems**

Lincoln Laboratory shipped the space payload for the Lunar Laser Communication Demonstration to the NASA Ames Research Center for integration onto the Lunar

Atmosphere and Dust Environment Explorer (LADEE) spacecraft. Also, the optical ground terminal was shipped to the White Sands Missile Range in New Mexico. This mission, launched in September 2013, demonstrated record-breaking high-rate laser communication from the lunar-orbiting LADEE spacecraft back to Earth.



*Figure 5. The Lunar Laser Communication Demonstration space terminal's optical module is shown during laboratory system testing. This view shows the mostly reflective "window" covering the 10 cm telescope, the open launch hatch, and the multilayer insulation blanketing that helps preserve a controlled thermal environment.*



*Figure 6. The Lunar Laser Communication Demonstration ground terminal makes use of four 15 cm transmit apertures and four 40 cm receive apertures to achieve data rates of 622 Mbits/s from a lunar orbiter to Earth.*

Lincoln Laboratory successfully completed the preliminary design of a compact airborne laser communication terminal that operates in an aggressive environment over a wide field of regard.

The Laboratory successfully completed shock-vibration and thermal-vacuum qualification of a space-compatible optical differential phase-shift-keyed modem that operates over a wide range of rates (2 Mbps–1.25 Gbps) with near-quantum-limited sensitivity.

Near-quantum-limited sensitivity was demonstrated in an optically preamplified coherent modem operating at 10 and 20 Gbps with world-record 2-photon-per-bit sensitivity.

A digital-transmitter-on-chip phased array under development uses custom silicon-germanium and gallium-arsenide application-specific integrated circuits and nonlinear waveform predistortion techniques to achieve linear efficient power transmitters.

This technology is applicable to future communications, radar, and electronic warfare systems.

A ground mobile terminal capable of connecting to the recently launched AEHF satellites was developed by the Laboratory and demonstrated in operational scenarios. The small-form-factor modem in this terminal is the first implementation that adheres to the future security and robustness requirements of the system.

A tactical airborne communications road map study was completed by the Laboratory and provided to the Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics to set the direction for next-generation wireless tactical systems.

The Lincoln Ka-Band Test Terminal was used to perform operational testing of the Wideband Global SATCOM System's wideband bypass mode for high-rate communications.

### **Cyber Security and Information Sciences**

A novel approach for measuring network security by using continuous monitoring techniques was developed. This methodology will become the basis for Federal Information Security Management Act security guidelines.

A team of researchers participated in two large Combatant Command military exercises and delivered two novel cyber situational awareness tools to cyber operational cells.

The Laboratory assisted in the modernization of the US Air Force Air Operations Center by developing and assessing a proof-of-concept integrated air and missile defense planner.

The Lincoln Adaptable Real-time Information Assurance Testbed (LARIAT) supported several national cyber exercises, including Cyber Flag, Red Flag, and Terminal Fury.

Lincoln Laboratory developed a new system that applies speech recognition technology to aid foreign language learners in developing their pronunciation skills; the initial system, which addresses Arabic pronunciation, has been delivered to the Defense Language Institute Foreign Language Center (DLIFLC) and is being pilot tested by DLIFLC students and faculty.



*Figure 7. A student from the Defense Language Institute Foreign Language Center is using Lincoln Laboratory's pronunciation assessment tool (NetProF) to improve her Arabic speaking skills.*



A study of cyber ranges was expanded to support the Test Resources Management Center. The study defined national needs, architectures, and standards for interoperability for all Department of Defense cyber ranges.

New techniques were developed for characterizing, analyzing, and searching large data sets; these techniques employ content graphs based on speaker and topic similarity metrics. A suite of shared cloud computing technologies was demonstrated; it included the simultaneous launch and execution of a virtual machine, a database, and data analytics.

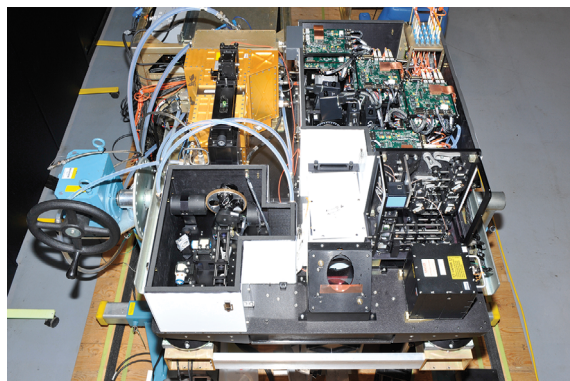
The Laboratory made significant progress in developing background models for social interaction networks and demonstrated the applicability of statistical graph analytics on a variety of data sets, including structured and unstructured reports, cyber security log files, and geointelligence.

A novel synchronous computer architecture that takes advantage of on-chip silicon photonics internetworking was developed.

### **Intelligence, Surveillance, and Reconnaissance Systems and Technology**

The Laboratory developed three wide-area motion imaging systems for visible and infrared persistent surveillance that are now operating in deployed situations. The Wide-Area Infrared System for 360° Persistent Surveillance (WISP-360) is an infrared, ground-based sensor that is integrated with existing tower-based surveillance systems. The Multi-Aperture Sparse Imager Video System (MASIVS), an 880-megapixel color airborne sensor, was deployed for collection of wide-area motion imagery. The Imaging System for Immersive Surveillance (ISIS), a 240-megapixel color optical sensor, was deployed for critical infrastructure protection.

The Laboratory's Airborne Ladar Imaging Research Testbed (ALIRT) system completed its 500th flight in support of overseas operations. This system has proven to be very valuable to US ground operations. Also, a new 3D ladar for the US Southern Command is nearing completion. The ladar is optimized for detection and characterization of structures under foliage cover, provides enhanced area coverage, and can help distinguish natural from man-made targets.



*Figure 8. The Laboratory is leveraging the success of the Airborne Ladar Imaging Research Testbed system to develop a 3D imaging ladar system for the US Southern Command to uncover clandestine activity in heavily foliated areas. The system's high area collection rates are enabled by quad 64 x 256 Geiger-mode avalanche photodiode arrays. The system is being integrated onto an aircraft for transition to operation in 2014.*

Radar processing techniques were developed to improve detection of small land and maritime targets. Several of these techniques were selected for transition into operational systems and systems under development.

A Laboratory-developed ultra-high-data-rate multiple-input multiple-output system sets new standards for non-line-of-sight, low-power communication links and enables efficient data exchange among ground-based ISR systems. Several prototypes were delivered to sponsors for operational testing.

Automation techniques were developed to reduce operator workload for distributed maritime surveillance systems. The Laboratory also developed and optimized sonar technology employed by autonomous undersea vehicles in antisubmarine warfare. The sonar signal processing provides computationally efficient target detection and classification and was selected for inclusion into other Navy distributed surveillance systems.

The Laboratory supported the development of the Air Force's new Dismount Detection Radar, which will provide wide-area persistent ground moving target indication (GMTI) for vehicles and dismounted personnel. This pod-based radar was designed to be integrated and fielded on an MQ-9 unmanned air vehicle. The Laboratory is incorporating advanced dismount signal processing modes into the contractor-developed system to provide warfighter capability and to verify the open architecture design.

The Laboratory's Pyxis software was operationally deployed for automated exploitation of GMTI radar data. Pyxis enhances detection of subtle activity patterns, supporting real-time cross cueing of other assets. The Laboratory also delivered cloud-based software analytics for analyzing massive unstructured intelligence data sets. These tools have proven effective in automated data mining and analysis and were deployed to multiple government agencies.

### **Tactical Systems**

Lincoln Laboratory continues to provide a comprehensive assessment of options for US Air Force airborne electronic attacks against foreign surveillance, target acquisition, and fire-control radars. This assessment includes systems analysis of proposed options, development of detailed models of threat radars and their electronic protection systems, and testing of various electronic attack systems.

The Laboratory developed a common open-systems architecture to upgrade legacy systems and to allow evaluation of foreign air defense threats. The architecture has been applied to upgrade older surveillance and target acquisition radars to include advanced signal processing and electronic protection, as well as instrumentation to support high-speed data recording and analysis capabilities.

Assessments of the impact of exporting advanced military systems were performed for the Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics and Congress to help inform the decision-making process for major export programs.

The Laboratory continued a detailed analysis of the impact of digital radio frequency memory-based electronic attacks on air-to-air weapon system performance. Results from flight testing, systems analysis, and hardware-in-the-loop laboratories have been used to improve US electronic protection systems and to inform senior DoD leaders' decision-making process for future system capabilities and technology investments.

An assessment of the capabilities and limitations of infrared sensors and seekers to support beyond-visual-range passive air-to-air engagements included systems analysis, development of detailed models of infrared search and track systems and imaging infrared missile seekers, and both laboratory and captive-carry testing of various surrogate systems.



*Figure 9. The dual-band, pod-mounted sensor developed for the Airborne Seeker Test Bed is used for airborne infrared imaging and data collection.*

The Laboratory is developing advanced architectures and technologies for use in next-generation counter-IED electronic attack systems. Activities this year culminated in a field demonstration of a significantly advanced capability intended for use in future Counter Radio-Controlled IED Electronic Warfare (CREW) systems.

Development is continuing on a number of significant US Air Force quick-reaction capabilities designed to field prototypes of critical new intelligence, surveillance, and reconnaissance technology supporting counterterrorism missions. These efforts leverage existing Air Force MQ-9 unmanned aerial vehicle assets and provide pod-based sensors and additional processing, exploitation, and dissemination capabilities. An initial set of prototype pods has been completed, integrated on MQ-9 aircraft, and designated for transition.

### **Space Control**

The Space Surveillance Telescope (SST), a 3.5-meter telescope for searching deep space, is nearing completion of its full checkout. Formal testing and evaluation has shown that the SST exceeds preprogram expectations.



The final precision alignment of the 37-meter-diameter primary reflector surface of the Haystack Ultrawideband Satellite Imaging Radar (HUSIR) was successfully completed. The aligned surface focuses the beam of the W-band radar to less than 0.006 degrees

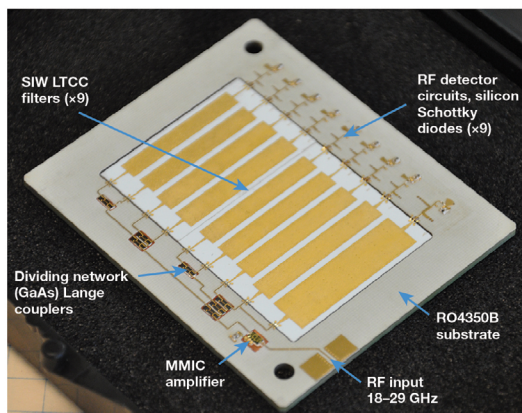


Figure 10. The ultra-compact nine-channel microwave spectrometer subassembly prototype utilizes low-temperature co-fired ceramic (LTCC) and substrate integrated waveguide (SIW) technology to enable high-performance microwave atmospheric sensing from very small platforms, including cubesats and unmanned aerial vehicles.

Lincoln Laboratory developed and tested an ultra-compact nine-channel microwave spectrometer prototype under the NASA Advanced Component Technology program. The packaged, flight-ready subassembly consumes 363 mW of power with a mass of 87.7 g. This new technology enables high-performance microwave atmospheric sensing from very small platforms, including cubesats and unmanned air vehicles.

To inform the development of a robust architecture for space situational awareness, the Laboratory conducted trade studies examining how existing and planned capabilities supporting other mission areas might be leveraged for application to space situational awareness.

Lincoln Laboratory participated in an experiment jointly sponsored by the Air Force Space Command and the Missile Defense Agency to demonstrate the utility and concept of operation for sharing operational sensors between mission areas. This effort involved the development of a tasking interface for an AN/TPY-2 X-band radar and the integration of a sidecar to enable real-time exposure of the AN/TPY-2 data net centrally over the Global Information Grid.

A new field site facility in Colorado Springs, CO, was opened. It will provide mission planning and data analysis in support of the operations of the Space-Based Space Surveillance spacecraft and will serve as an integration and test facility for introducing new capabilities for space situational awareness.

The Tactical Space Situational Awareness initiative integrates Laboratory sensor technology programs with net-centric, multisensor fusion test beds to operate the Lincoln Space Surveillance Center as an operational prototype for a modern space control architecture. Initial testing demonstrated a robust new object discovery system,

routine tactical handoffs from optical search sensors to radar, and a dramatically improved surveillance capacity of existing sensors.

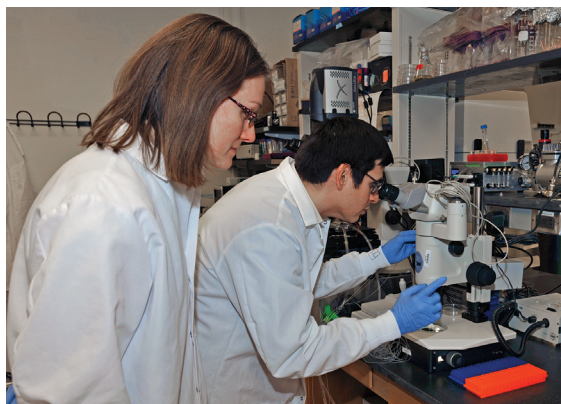
The Laboratory contributed to on-orbit checkout of the Suomi National Polar-orbiting Partnership satellite launched on October 28, 2011. Data processing algorithms of the Cross-Track Infrared Sounder, the Advanced Technology Microwave Sounder, and the Visible/Infrared Imaging Radiometer Suite were optimized and validated and are now entering operational use.

### **Homeland Protection**

The Next-Generation Incident Command System, developed in partnership with the California Department of Forestry and Fire Protection (CAL FIRE), is being deployed statewide by CAL FIRE and operationally evaluated by first responders from multiple state emergency management agencies and the Fire Department of New York.

The Laboratory continues to lead technology development and architectures for countering chemical threats and weapons of mass destruction. Accomplishments include threat phenomenology measurements, gap and technology analysis, and design and testing of new capabilities for warfighters and the homeland.

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, noise-induced hearing loss, and musculoskeletal load injuries among service members.



*Figure 11. Researchers in the Bioengineering Systems and Technologies Group examine a microfluidic integrated nanopore device (MIND) designed to measure chromatin modifications on single molecules.*

Advanced video analytics technology is being developed for a variety of applications, including crowded domains such as transportation centers and sparsely populated locations such as border regions. Emphases include attribute video-content search, detection and tracking across large camera arrays, and summarization tools.

The Laboratory is developing serious game capabilities to engage end users in exploring emerging decision support technologies and to enhance experiential learning for decision makers. Game applications areas include law enforcement, public health, and disaster response.

The Imaging System for Immersive Surveillance consists of a custom 240-megapixel sensor and automated video exploitation algorithms for ground-based surveillance supporting critical infrastructure protection. Sponsored by the DHS Science and Technology Directorate (S&T), ISIS is undergoing operational testing in multiple venues.

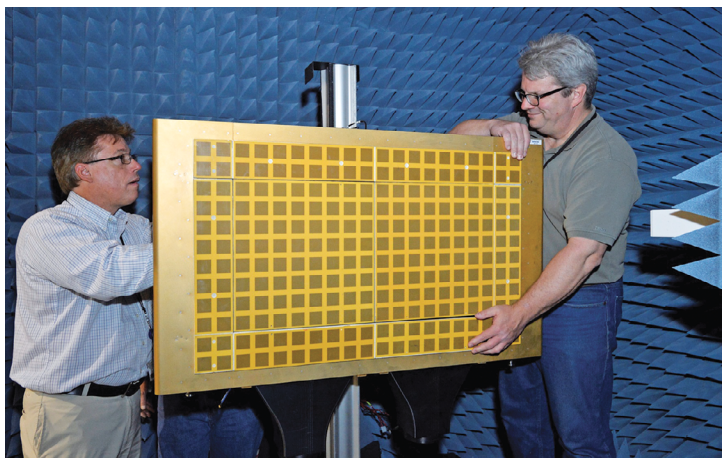
The Laboratory is developing advanced incident-response capabilities for the US Coast Guard and is informing acquisition strategies through assessments of search and rescue, port security, cargo-vessel targeting, and environmental protection missions.

The Laboratory is providing assessment support to the DHS S&T Homeland Security Advanced Research Projects Agency. Activities are focused on informing technology investment directions and strategies. These efforts span a broad range of missions, with key examples in border security technologies.

A Grand Challenge being led by Lincoln Laboratory for the Defense Threat Reduction Agency is focused on metagenomic algorithms to rapidly and accurately characterize DNA sequence information that is mixed within complex clinical and environmental samples.

### **Air Traffic Control**

System performance studies and hardware development were conducted for the Multifunction Phased Array Radar (MPAR) project to mitigate risks associated with cost, siting, frequency interference, and hazardous wind-shear detection capability. The program is constructing a 10-panel demonstration array to quantify performance parameters and to collect field data for signal processing and calibration technique refinement.



*Figure 12. Lincoln Laboratory is continuing the development and extension of its 64-element Multifunction Phased Array Radar prototype, building toward a 10-panel demonstration array.*

Lincoln Laboratory continued to support the technology transfer of the Route Availability Planning Tool (RAPT), currently operational in New York and Chicago, to deployment in Philadelphia and the Potomac region. RAPT is also being extended to include departure demand information and to aid in arrival route management in the presence of convective weather.

The Laboratory supported flight tests, human-in-the-loop simulations, and fast-time computer modeling of advanced flight management systems on aircraft performing Next Generation Air Transportation System (NextGen) trajectory-based operations. Results from these activities are being used to develop requirements for automation systems and winds-aloft forecasts that will enable aircraft to establish more efficient and robust arrival metering times and spacing intervals.

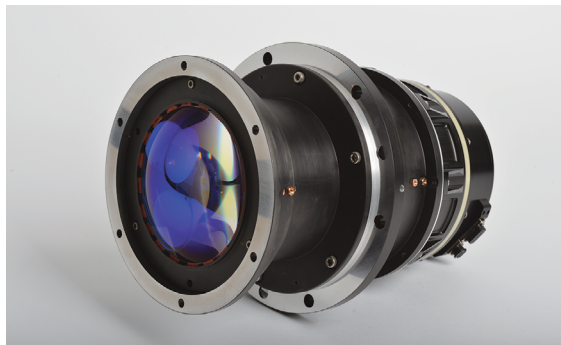
The NextGen Weather Processor (NWP) consolidates multiple legacy FAA weather processing platforms and introduces new functionality, such as the short-term (0–8-hour) thunderstorm-forecasting technology developed by Lincoln Laboratory. The Laboratory is leading efforts to define requirements for the NWP, to refine and test a reference technical architecture, and to provide technology exhibits for use by the FAA in requests for proposals from industry.

The Laboratory is developing standards and requirements to provide safe unmanned aircraft system sense-and-avoid (SAA) capabilities. Also under development are collision avoidance algorithms for ground-based and airborne SAA. The Laboratory supported the successful engineering demonstration of its algorithms in Army and Air Force ground-based architectures deployed to Dugway, UT, and Gray Butte, CA, respectively. The Laboratory's prototype lightweight, low-power, airborne radar for SAA was successfully flight tested to collect data to refine sensing and algorithm requirements.

Lincoln Laboratory continues to play a key role for the FAA in developing the NextGen airborne collision avoidance system, ACAS X, which will support new flight procedures and aircraft classes. Efforts in 2013 focused on tuning ACAS X to meet operational suitability and pilot acceptability performance metrics by lowering collision risk while producing fewer disruptive alerts than current systems.

## Engineering

Lincoln Laboratory's key contributions to a proposal for the Transiting Exoplanet Survey Satellite (TESS) included the design, fabrication, and testing of a prototype telescope for the satellite. Successful demonstration of the telescope design was a major risk factor for the system. The proposal presented by the MIT Kavli Institute for Astrophysics and Space Research was accepted by NASA.



*Figure 13. The Transiting Exoplanet Survey Satellite (TESS) system is composed of four optical sensors designed to map out the entire sky in the search for transiting exoplanets. Shown here is one of the prototype telescopes designed, built, and tested to support risk-mitigation efforts for the TESS project selected by NASA for a 2017 mission.*



The Laboratory continued to invest in cutting-edge fabrication and electronic assembly technologies, including sinker electrical discharge machining technology and a robotic conformal coat system for printed circuit boards.

All three modules for the Lunar Laser Communication Demonstration completed fabrication, integration, and environment testing, and these modules were shipped to the NASA Ames Research Center for integration on the Lunar Atmosphere and Dust Environment Explorer spacecraft.

The Laboratory continued to support efforts by the MIT Department of Aeronautics and Astronautics to design, build, and test the cubesat bus for the Micro-sized Microwave Atmospheric Satellite.

New laboratories for optical system testing and development of autonomous systems were designed and built to allow those technology areas to continue to grow within the engineering mission area.

Modifications of the hydrostatic azimuth bearing of the Haystack Ultrawideband Satellite Imaging Radar were made to allow the program to move forward with control system testing and initial X-band operation. Alignment of the antenna surface was successfully demonstrated at the levels needed for W-band operation.

An engineering development unit for the Rapid Agent Aerosol Detector system was fabricated and assembled for use in a variety of validation tests that will lead to technology transfer of the system design and eventual high-rate production by industry.

## **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**

#### ***Cyber Security and Information Sciences***

During the past year, the Laboratory's key management software was packaged for use by Draper Laboratory. In addition, software to test and measure the performance of newly developed cryptographic protocols was transferred to multiple industry and academic partners for the Security and Privacy Assurance Research Program.

The Lincoln Adaptable Real-Time Information Assurance Testbed (LARIAT) traffic-generation tools were transferred to more than 10 new users.

The Lincoln Automated Malicious Binary Data Analyzer (LAMBDA) and BETA malware analysis and transformation tools were transitioned to the sponsor and users.

### ***Communication Systems***

The design of a high-altitude electromagnetic pulse hardened transportable SATCOM terminal was tested, and industry-built versions were delivered to the Air Force.

A simulation model of a future protected SATCOM waveform was developed and delivered to 16 industry teams for use in analysis and early prototyping.

The Laboratory provided the Defense Information Systems Agency with a guide for core radio management information base and proxy implementation. This document defines the management of current and future radio systems with a common network management interface.

### ***Tactical Systems***

The Laboratory is supporting and further developing a sensor approach designed for route-clearance engineer teams to use on a robotic platform. The initial robotic capability has been transitioned to industry for production. The Laboratory continues to assess and prototype significant advancements to this technology.

A field-hardened prototype of a new ground-penetrating radar technology significantly advances the state of the art in antenna array and processing technology. This prototype has been integrated on a military vehicle and transitioned to the Army for operational use.

### ***Space Control***

The Laboratory contributed core algorithm technology to the Atmospheric Infrared Sounder (AIRS) instrument suite, released to the public on March 1, 2013. AIRS, which is onboard the NASA Aqua satellite, produces high-resolution atmospheric soundings in clear and cloudy conditions.

### ***Air and Missile Defense Technology***

Lincoln Laboratory developed a phased array radar simulation system to design and test open system architecture technical concepts and radar processing algorithms for ground-based air defense radar systems. These technologies were transferred to the government to support the development of the Three-Dimensional Expeditionary Long-Range Radar system.

Under US Navy sponsorship, radar signal processing and calibration algorithms were developed and transferred to government contractors for subsequent integration into the E-2D Advanced Hawkeye. The E-2 Hawkeye is the Navy's all-weather, carrier-based tactical battle management airborne early-warning and command-and-control aircraft.

## R&D 100 Awards

Six Lincoln Laboratory technologies were named 2014 recipients of R&D 100 Awards. The 100 most technologically significant innovations introduced during the previous year are selected annually by *R&D Magazine* as award recipients. The winning technologies listed below represent work in several diverse areas of research:

- Airborne Sense and Avoid Radar Panel—a novel stepped-notch antenna array that supports aircraft and weather detection and tracking modes in a single multifunction aperture
- Curled Microelectromechanical Switch—a compact, low-loss, reliable radio frequency switch that achieves a large impedance change
- Haystack Ultrawideband Satellite Imaging Radar—a ground-based, dual X- and W-band sensor that produces very-high-resolution images of space objects
- Localizing Ground-Penetrating Radar—a robust localization sensor that provides real-time global-position estimates based on prior mapping of subsurface ground features
- Lunar Laser Communication System—an optical system that achieves very high uplink and downlink data rates between a space terminal and a terminal on Earth
- Wide-Area Chemical Sensor—a highly precise, self-referencing spectrometer that measures the concentrations of specified target particulates in the air

## 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 continuing dialogue that enhances technology development and provides direction for future research. The following workshops were held this year:

- Advanced Research and Technology Symposium
- Advanced Technology for National Security Workshop
- Air and Missile Defense Technology Workshop
- Air Vehicle Survivability Workshop
- Anti-access/Area Denial Systems and Technology Workshop
- Cyber and Netcentric Workshop
- Defense Technology Seminar
- Intelligence, Surveillance, and Reconnaissance Systems and Technology Workshop
- Lincoln Laboratory Communications Conference
- Mechanical Engineering Technology Symposium



- Software Engineering Symposium
- Space Control Conference
- Homeland Protection Workshop Series (two one-day seminars held in Virginia)
- Air Traffic Control Workshop (coordinated with the Federal Aviation Administration and held in Washington, DC)

In addition, Lincoln Laboratory is a technical partner for the IEEE High Performance Extreme Computing Conference, the IEEE SOI-3D-Subthreshold Microelectronics Technology Unified Conference, and the IEEE International Symposium on Technologies for Homeland Security.

## **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, 2013, and June 30, 2014, Lincoln Laboratory staff published 137 papers in proceedings from such conferences and 85 articles in technical journals.

The Laboratory publishes the *Lincoln Laboratory Journal*, which contains comprehensive articles on current major research and journalistic pieces highlighting novel projects. In fall 2013, a special issue on graphs and networks was published to highlight work being done in this increasingly important area. In spring 2014, a multi-topic issue featured articles on the Laboratory's innovative digital-pixel focal plane array and wavelength beam-combining laser technology, both of which were past winners of R&D 100 Awards. The Laboratory also 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 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 Laboratory. In 2013–2014, 22 military officers worked at the Laboratory under fellowships. In addition, in summer 2013, 30 midshipmen from the US Naval Academy, 7 cadets from the US Air Force Academy, and 10 cadets from the US Military Academy at West Point participated in an educational exchange program at the Laboratory.

## **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 can spend two summers as paid Laboratory 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 2013, two students chose to do their thesis research at Lincoln Laboratory. The Laboratory also employs other research assistants from across MIT's engineering departments; currently, 32 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 2013, 11 students worked under these programs.

Each summer, the Laboratory hires undergraduate and graduate students from top universities as interns in technical groups. In summer 2013, 87 undergraduates and 87 graduate students from 72 different schools worked at the Laboratory. In addition, cooperative education students from area colleges, such as Northeastern University and Wentworth Institute, work at Lincoln Laboratory throughout the year. During the 2014 spring semester, 47 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 2013, seven WPI students were accepted as interns.

### **Collaboration with the MIT Campus**

Initiatives supported by the MIT campus 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.

#### **MIT Lincoln Laboratory Beaver Works Center**

On November 12, 2013, MIT president L. Rafael Reif, Lincoln Laboratory director Eric D. Evans, and MIT School of Engineering dean Ian A. Waitz cut the ribbon to officially open the MIT Lincoln Laboratory Beaver Works Center. The center, a joint venture between Lincoln Laboratory and the MIT School of Engineering, is envisioned as an incubator for research and innovation. It is intended to facilitate project-based learning, a hallmark of an MIT education, and to leverage the expertise and enthusiasm of MIT faculty, students, and researchers and Lincoln Laboratory staff to broaden research and educational partnerships.

Lincoln Laboratory has been engaged in ongoing collaborations with departments and centers at MIT to provide project-based educational experiences to undergraduate and graduate engineering students. The new center provides facilities for these educational activities: areas for collaborative brainstorming, workshops and tools for the fabrication of prototype systems, and space for classroom-style instruction. Beaver Works supports student involvement in a range of research and educational pursuits, including two-semester, course-based capstone projects; joint and individual research initiatives; and Undergraduate Research Opportunities Program internships.

The 5,000-square-foot center, located in Technology Square in Cambridge, is open to MIT students and faculty and Lincoln Laboratory staff. The center has been a resource for a

number of educational events, including two multiday workshops, one in February and one in June, on the application of technology to humanitarian assistance and disaster relief efforts and an open house during the Cambridge Science Festival in April.

This year's capstone projects included efforts focused on the development of unmanned aerial vehicles (Department of Aeronautics and Astronautics), the development of an aluminum-water fuel cell for an autonomous undersea vehicle (Department of Mechanical Engineering), the design and deployment of a network of sensors to monitor air quality around the MIT campus (Department of Civil and Environmental Engineering), and investigation of the imaging challenges faced by mobile devices (Program in Media Arts and Sciences).

The Beaver Works program offers unique benefits:

- MIT faculty and students gain awareness of national security problems and strengthen their relationship with DoD sponsors.
- 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, 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.

### **Research Collaborations**

There are multiple mechanisms for direct support of and collaboration with MIT campus researchers. Each year, the Laboratory spends approximately 8–10% 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 Laboratory staff and MIT researchers. In addition, the Advanced Concepts Committee provides short-duration grants to MIT faculty and Lincoln Laboratory 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 as from external program sponsors in the Department of Energy, DoD, NASA, and other government agencies.

### **Infrastructure**

Lincoln Laboratory's service departments continue to augment the infrastructure that supports the research and prototyping activities of the technical divisions.

The Contracting Services Department supported the Laboratory's federally funded research by issuing approximately 51,000 procurement transactions with a value of \$401.5 million in 2013. To maximize business process efficiencies, the Laboratory encouraged the use of electronic procurement tools; between July 2013 and June 2014, staff from outside the Contracting Services Department directly placed approximately 25,000 procurement transactions through the use of e-catalogs and electronic procurement cards.

In October 2013, the department successfully rolled out an online release review tool. This new system allows the Laboratory to efficiently process release requests that satisfy the requirements of the prime contract and the sponsoring agreement and makes the process more transparent and auditable than the previous system.

Lincoln Laboratory nominated the Vtech Engineering Corporation from Andover, MA, for the US Small Business Administration's Small Business Subcontractor of the Year award, and Vtech was named the 2014 National Subcontractor of the Year during the National Small Business Week celebration in May. In addition, the Laboratory's small business program received the Defense Contract Management Agency's "outstanding/low risk" rating, the agency's highest ranking.

The Facility Services Department manages Lincoln Laboratory's capital renewal program, which encompasses two main elements: 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 fiscal year 2014, as part of its annual capital investment projects, the department initiated studies of the electrical infrastructure and the Laboratory's chiller plant. Both studies will address the need for upgrades to the existing systems and the options for infrastructure expansion in support of the proposed new Laboratory buildings. The design phase for an extensive upgrade to the Laboratory's chemical storage facility was completed. This upgrade will be undertaken in fiscal year 2015.

The Laboratory initiated a formalized 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. In 2014, the program investment was \$8.75 million. Deferred maintenance projects are continually prioritized on the basis of their impact on or critical nature relative to the Laboratory's mission. Project categories include life safety; building envelope repairs; heating, ventilation, and air conditioning (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 completed in 2014 were a complete replacement of the HVAC systems in Building C; replacement of the windows, façade, and roof in Building L-Infill; and replacement of the critical exhaust fans in the Microelectronics Laboratory. Work also continued on upgrading the gas-detection systems throughout the Laboratory.

The Facility Services Department also manages the Laboratory's transportation services and commuter support programs. In 2014, Lincoln Laboratory received a Massachusetts Excellence in Commuter Options Award from MassCommute, a nonprofit organization that works with the Massachusetts Department of Transportation to encourage commuters to use alternatives to single-vehicle ridership. The Laboratory was recognized in the Leadership in Commuter Options category for the success of its carpool and vanpool programs.

The Financial Services Department continued to focus on financial planning and scenario modeling to address the government shutdown in the fall and the uncertainty of the impact of sequestration on the government budget. Much effort was devoted to defining and quantifying risks to the funding portfolio. Ongoing efforts include incorporating these risk profiles into the reporting environment via the new suite of analytic tools introduced in the Data Warehouse. Continued progress was made in automating the Laboratory's payment processes, with additional vendors being added to both electronic invoicing and Automated Clearing House payments. A test exercise was done to determine the pros and cons of using radio frequency identification for tracking of property assets.

In 2014, the Information Services Department (ISD) delivered a new strategic plan and initiated a move to an IT as a service and service catalog approach. Service and infrastructure enhancements across the department included procurement of equipment for a complete refresh of core networks and security. ISD made major cyber security improvements, including additional layered protection and detection systems and enhanced vulnerability assessment and analysis capabilities. Expansion of the VoIP telephone platform to remote sites continued, along with large-scale migration to standardized Linux platforms and virtualized servers. ISD also continued to expand embedded service support models.

Various initiatives were aimed at improving information services across the Laboratory:

- Several new websites were created, including sites for conferences and courses, the Technology Office, and the MIT Lincoln Laboratory Beaver Works Center.
- A new e-forms capability was introduced.
- Enhancements of the document management system and the intranet were put into production.
- A new service supporting Apple iOS devices was initiated with custom security controls.
- A major migration of the Laboratory-wide email system was completed.
- The new system for desktop access to geospatial data and imagery was brought into production.
- ISD supported an increasing number of events with photography and displays, and editing and production of reports increased.
- A new online learning center was created for support and delivery of training for the Laboratory.

The Business Process Improvement Program, coordinated by ISD and the Financial Services Department, continued to roll out new tools that aid financial and business operations via both SAP and non-SAP systems. These tools included a new reporting and analysis system (Lincoln Business Intelligence Suite), anticipated-funds tracking, and various service department process improvement tools. Standardization of hosting environments continued for numerous non-SAP systems. In-depth planning began for major business changes at the Laboratory, including contract renewal and procurement system upgrades.

The Security Services Department (SSD) led the effort that earned Lincoln Laboratory its eighth consecutive “superior” security rating from the US Air Force’s 66th Air Base Group Information Protection Office. In calendar year 2013, 40 successful government security-related reviews were conducted by multiple government agencies.

SSD strengthened its program at the Laboratory by accomplishing the following strategic goals:

- Managed an independent vulnerability assessment. According to the review team’s findings, the Laboratory’s current IT security posture is effective.
- Conducted an IT Security Alert Level 5 tabletop exercise with representation across SSD, the Information Services Department, the Cyber Security and Information Sciences Division, and the director’s office. The exercise focused on deterring and responding to advanced network attacks to prevent data exfiltration and deleterious effects on Laboratory services.
- Implemented new forensic analysis tools that improved the protection of Laboratory data through continuous keyword scanning targeted at insider threat remediation.
- Modernized video teleconferencing capabilities Laboratory-wide to enable research, maximize meeting efficiency, and promote less reliance on local and domestic travel.
- Improved efficiency and execution by leveraging technology, automation, and process improvements to further enhance SSD’s ability to deliver quality services, including tracking of security clearance and commercial background investigation requests.
- Planned and executed a Laboratory-wide rebadge effort to transition to a more secure badge stock that improves access-control security measures.
- Coordinated the implementation of the mandatory Hanscom Air Force Base (HAFB) Defense Biometric Identification System, ensuring seamless execution and minimal effects on MIT personnel.
- Provided security support to enable the success of several high-profile Laboratory-hosted conferences and sponsor-requested technical review days.
- Organized the fifth annual “security education and awareness week”; this year’s activities emphasized insider threat indicators, information security best practices, operations security, and counterintelligence awareness.
- Reduced security incidents by approximately 9% via security education and effective leadership.

- Formulated and implemented policies, plans, and actions designed to provide protection against threats of vandalism, accidental destruction, espionage, and sabotage.
- Continued to strengthen the Laboratory emergency preparedness program by hosting an active threat shooter tabletop exercise that involved the Laboratory Emergency Action Team, HAFB security forces, local law enforcement, and Laboratory volunteers.
- Heightened employee emergency preparedness awareness by releasing a Laboratory-wide emergency preparedness plan.

## 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 2013–2014 educational outreach activities are described below.

In summer 2014, the Lincoln Laboratory Radar Introduction for Student Engineers program offered 18 soon-to-be high school seniors from across the country a two-week project-based course on radar fundamentals. The program included instructional sessions on the basics of radar systems and radar imaging, workshops for building radar systems that can perform range-Doppler imaging, and opportunities to demonstrate the performance of the radars built during the workshops. During the two weeks of the program, students are housed in a dormitory at MIT and attend sessions on campus to learn more about the college application and financial aid processes. Trips to the Laboratory's radar field site in Westford, MA, and to Boston attractions round out the two-week experience.

This year, Lincoln Laboratory staff from the Cyber Security and Information Sciences Division and the Communications and Community Outreach Office mentored three five-member teams of high school students who competed in cyber defense challenges run by the Air Force Association's CyberPatriot program. Although these teams of first-year participants reached the semifinal rounds of the 2013–2014 national CyberPatriot cyber defense competition, their scores were just shy of the requisite score for an invitation to the finals in Washington, DC.



*Figure 14. Students participating on the Lincoln Laboratory-sponsored CyberPatriot teams meet regularly at the MIT Lincoln Laboratory Beaver Works Center to practice techniques for detecting and thwarting malicious attacks on computer networks.*



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. Lincoln Laboratory sponsored two teams in the FIRST Tech Challenge competitions, geared to participants in grades 7 to 12. In the 2013–2014 academic year, the MightyBots team competed in the state championship event. In addition, the Laboratory coached 12 teams taking part in the FIRST LEGO League challenges, designed for children in grades 4 to 8. Youngsters enrolled in kindergarten to grade 3 can explore the activities offered by the Junior FIRST LEGO League program; three teams in this category were guided through model building by Laboratory mentors. In addition, ROLL volunteers assist FIRST teams from schools in Boston, Waltham, Lexington, Weston, and Shrewsbury, MA, by providing technical guidance and staging scrimmages.

Science on Saturday, the Laboratory'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. This year, a guest presenter was invited to conduct the April demonstration; Zarin Machanda, PhD, a primatologist with the Kibale Chimpanzee Project, involved the audience in an exploration of chimpanzees' social behavior. Other offerings for the 2013–2014 season were a hands-on engineering "fair" and demonstrations on robotics, the visual spectrum, and chemistry.

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, which names asteroids in honor of science fair winners—are all continuing.

### **Community Service**

The Laboratory's community service program is strong. LLCO helps increase Laboratory employees' awareness of events sponsored by charitable organizations. The Memory Walk for the Alzheimer's Association raised more than \$25,000 to provide services to patients in Massachusetts and New Hampshire. LLCO again facilitated participation in the Bike and Hike the Berkshires event, which raises funds for the Multiple Sclerosis Society; \$7,528 was raised by the bike and hike team. Laboratory employees also walked, ran, and bicycled for a number of other causes this year: the Free to Breathe 5K for lung cancer, the AIDS walk/run, the CancerCare walk, and the Harbor to Bay bike ride for AIDS. In addition, the Laboratory community helped Sarah Lewis, a project manager in the Information Services Department and a Boston Marathon runner on the MIT Strong team, raise more than \$4,500 for the Collier Fund; this fund was established to honor MIT police officer Sean Collier, who was killed in the line of duty in 2013.

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 Toys for Tots drive. Support Our Troops, one of LLCO's first community giving programs, is an ongoing campaign to collect and mail food, toiletries, and books to US soldiers overseas; this year, program volunteers again sent approximately 250 packages to troops overseas.

## **Summary**

Department of Defense interest in Lincoln Laboratory's research and prototype development remains strong. Current programs extend from fundamental investigations to developmental engineering and operational testing of prototype systems. The Laboratory's range of programs continues to be well balanced with system development in core missions, innovative research projects, and large-scale programs. Technology transfer remains an emphasis in all mission areas. Through its technology transfer activities, the Laboratory helps ensure that the US military has access to leading-edge, useful systems and that the defense industry remains competitive. Ongoing improvements to administration and infrastructure help sustain the Laboratory's ability to achieve technical excellence.

Emerging national concerns are leading to opportunities for research and development in areas such as cyber security, autonomous systems, 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.

Our educational outreach program has expanded in both depth and reach to students in underserved communities. In August, we will conduct a two-week program to prepare high school freshmen and sophomores from Boston and Cambridge for rigorous courses in mathematics. As a means to help prepare the next generation of scientists and engineers, such educational programs are seen as part of our national security mission. Lincoln Laboratory employees are also encouraged to become involved in charitable activities that provide needed resources to local communities and organizations; to that end, the Communications and Community Outreach Office facilitates opportunities for employees to participate in outreach events. 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**