# 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 core areas of sensors, information extraction (signal processing and embedded computing), integrated sensing, 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.

For the federal fiscal year 2010, Lincoln Laboratory is projected to receive approximately $892 million that will support the efforts of about 1,500 professional technical and managerial staff and 1,400 support personnel; outside procurement will exceed $317 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 Oceanographic 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 inception in 1951. For 59 years, Lincoln Laboratory has provided advanced technological solutions to meet national security needs, earning a Secretary of Defense Medal for Outstanding Public Service in 2001 for its half-century of distinguished technical innovation and scientific discoveries.

## 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, integrity, and innovation, all of 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.

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 Office, as a primary advisor, enable cross-divisional research teams to coordinate and manage the technical and programmatic challenges of large-scale developments.

### *Key Changes to the Laboratory's Structure*

The Laboratory restructured three divisions to align research and development with areas that are increasingly important to the nation: homeland protection, cyber security, tactical systems, and intelligence, surveillance, and reconnaissance (ISR). The refocused Homeland Protection and Air Traffic Control Division will develop and expand the Laboratory's work on chemical and biological defense, border security, and the safety of the National Airspace System. The mission of the new ISR and Tactical Systems Division will be the development of systems for surface and undersea ISR, counterterrorism and counterinsurgency, and tactical operations. The Communications and Information Technology Division, reorganized as the Communication Systems and Cyber Security Division, will continue work to enhance the capabilities of the nation's defense communication systems and will grow programs to protect the nation's networks and critical infrastructure. In addition, since work in advanced electronics is encompassing more than solid-state or electro-optical technologies, moving toward multidisciplinary approaches and increased use of biotechnology and innovative chemistry, the Solid State Division was renamed the Advanced Technology Division.

The division restructuring was accompanied by several leadership changes:

- Dr. Robert T.-I. Shin was appointed head of the ISR and Tactical Systems Division, and Dr. Robert G. Atkins, Dr. Curtis W. Davis, and Dr. James Ward were appointed assistant heads of the division.
- Dr. Israel Soibelman was appointed head of the Homeland Protection and Air Traffic Control Division, and James M. Flavin and Dr. Mark E. Weber were appointed assistant heads of the division.
- Other leadership changes included the following:
- Dr. Michael T. Languirand was appointed assistant head of the Engineering Division.
- Craig E. Perini was appointed assistant head of the Aerospace Division.

Figure 1 shows an overview of the Laboratory's current organizational structure.

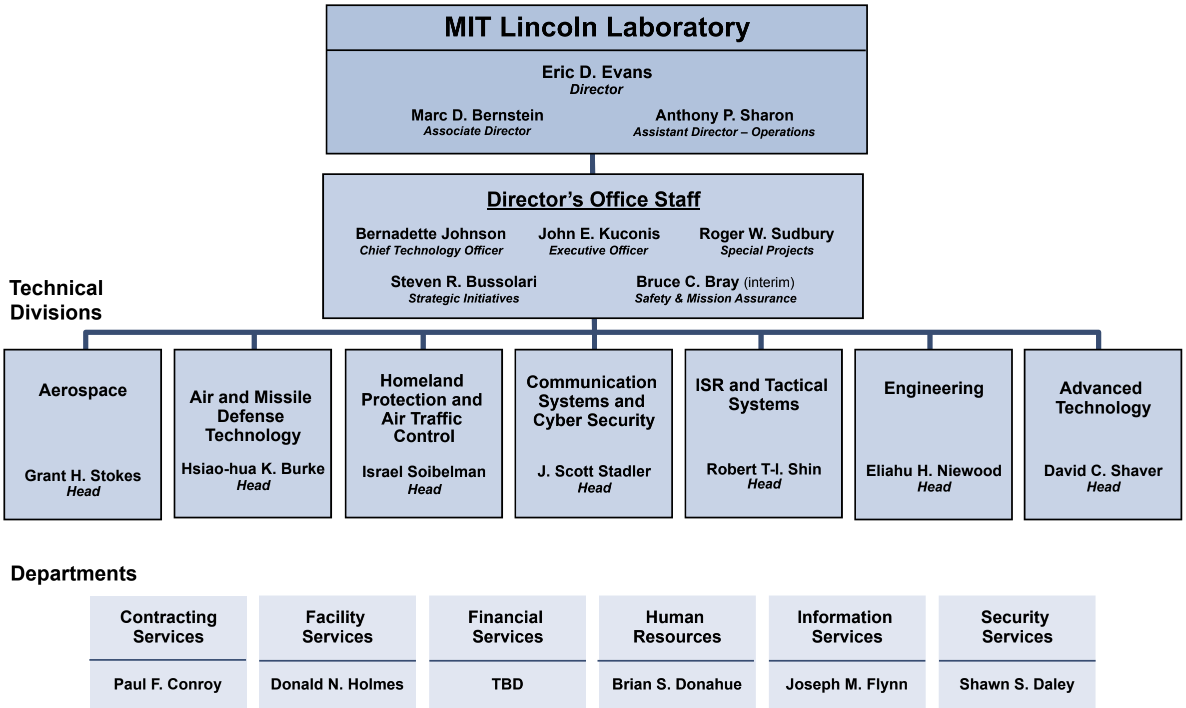


*Figure 1. Lincoln Laboratory's organizational structure.*

## Staff

Key to maintaining excellence at Lincoln Laboratory is its technical staff of highly talented scientists and engineers. Of new Laboratory staff, 65% to 75% are hired from the nation's leading technical universities. The Laboratory recruits at more than 65 colleges and universities nationwide. The makeup of the Laboratory staff by degree and academic discipline is shown in figure 2. The total number of Laboratory employees is 3,000, with 1,500 technical and managerial staff members.

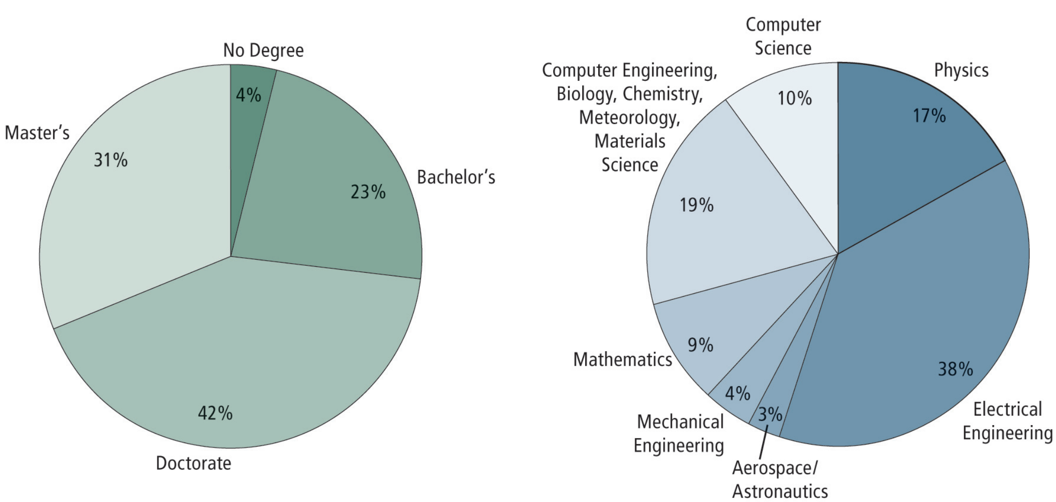


*Figure 2. Composition of professional staff by academic degree (left) and academic discipline (right).*

### *Staff Honors and Awards*

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

- The Department of Defense appointed William P. Delaney and Dr. Eric D. Evans to the Defense Science Board as a senior fellow and as a member, respectively.
- Roger W. Sudbury was selected for the 2010 Distinguished Service Award of the IEEE Microwave Theory and Techniques (MTT) Society to honor his "outstanding and dedicated service to the advancement of the MTT Society."
- Dr. Grant H. Stokes and Dr. Douglas A. Reynolds were named fellows of the *Institute of Electrical and Electronics Engineers* (IEEE).
- Alan D. Bernard received the National Defense Industrial Association's Rear Admiral Robert H. Gormley Combat Survivability Award for Leadership.
- Two teams on which MIT Lincoln Laboratory technical staff served—the Theater Critical Measurements Program team and the Burnt Frost team—received Missile Defense Agency Technology Achievement Awards in 2010. Dr. Keh-Ping Dunn, Dr. Daniel A. O'Connor, Dr. Donald S. Coe, David L. Immerman, and Christopher B. Johnson served on the Theater Critical Measurements Program team. Dr. R. Louis Bellaire was a member of the Burnt Frost team.
- Dr. Tso Yee Fan and Dr. David R. McElroy received MIT Lincoln Laboratory 2009 Technical Excellence Awards.
- Dr. Mykel J. Kochenderfer, Matthew W.M. Edwards, Leo P. Espindle, Dr. James K. Kuchar, and J. Daniel Griffith received the 2009 MIT Lincoln Laboratory Best Paper Award for "Airspace Encounter Models for Estimating Collision Risk," which was published in the *AIAA Journal of Guidance, Control, and Dynamics.*
- Dr. Eric A. Dauler and Dr. Andrew J. Kerman of Lincoln Laboratory, along with co-inventors professor Karl K. Berggren, Dr. Joel Yang, and Dr. Vikas Anant of MIT, received the 2009 MIT Lincoln Laboratory Best Invention Award for Multi-element Optical Detectors with Sub-wavelength Gaps.
- Dr. Jakub T. Kedzierski, Dr. Craig L. Keast, Paul D. Healey, and Dr. Peter W. Wyatt of Lincoln Laboratory, along with professor Jing Kong and graduate students Pei-Lan Hsu and Alfonso Reina from MIT, received the IEEE Electron Devices Society's George E. Smith Award for the paper "Graphene-on-Insulator Transistors Made Using C on Ni Chemical-Vapor Deposition."
- Dr. Thomas G. Macdonald received the 2010 Armed Forces Communications and Electronics Association Meritorious Award for Engineering.

### *R&D 100 Awards*

Five Lincoln Laboratory technologies were named 2010 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 Laboratory recipients listed below represent diverse fields.

- Geiger-Mode Avalanche Photodiode Detector Focal-Plane Arrays: a two-dimensional array of ultrasensitive solid-state photodetectors, each of which can measure the arrival time of single photons. Developers: Simon Verghese, Richard Marino, Alvin Stern (retired), Brian F. Aull, Bernard B. Kosicki, Robert K. Reich, Bradley J. Felton, David C. Shaver, Andrew H. Loomis, Douglas J. Young, Alexander K. McIntosh, David C. Chapman, Joseph P. Donnelly, Douglas C. Oakley, Antonio Napoleone, and Erik K. Duerr.
- Subwavelength-Separated Superconducting Nanowire Single-Photon Detector Arrays: a component in an optical detection system that enables broadband single-photon detection with high efficiency and low noise at rates exceeding one billion photons per second. Developers: Eric A. Dauler and Andrew J. Kerman of Lincoln Laboratory, MIT professor Karl K. Berggren, and Vikas Anant and Joel K.W. Yang, former graduate students at MIT.
- Digital-Pixel Focal-Plane Array: a complementary metal-oxide semiconductor readout-integrated circuit for infrared imaging. Fast on-chip processing provides an extreme dynamic range from a minimally sized package. Developers: Michael Kelly, Kenneth Schultz, Lawrence Candell, Daniel Mooney, Curtis Colonero, Robert Berger, Brian Tyrrell, and James Wey.
- Runway Status Lights: a system integrating data from airport surveillance sources to control in-pavement lights that directly alert pilots to potential runway incursions. Developers: James R. Eggert and Eric M. Shank.
- Miniaturized Radio-Frequency Four-Channel Receiver: the smallest, least-power-demanding receiver that can detect frequencies over a six-octave range. Developers: Helen H. Kim, Matthew D. Cross, Merlin R. Green, Daniel D. Santiago, and Sabino Pietrangelo.

### *Professional Development*

Lincoln Laboratory's commitment to the professional development of its staff is shown by the variety of educational opportunities offered. The Laboratory earned the 2010 IEEE Educational Activities Board's Professional Development Award for "for exemplary leadership in providing programs for its employees, IEEE members, and other professionals for continuing education and professional development."

The Technical Education Program offers semester-length courses taught by Lincoln Laboratory technical staff or by outside experts, often professors from MIT. The 2009–2010 schedule included the following courses:

- Human-Machine Interface and Decision Support
- Understanding and Using Digital Signal Processing
- Net-centric Operations
- Linear Algebra
- Introduction to Radar Systems

The Engineering Division developed and taught a series of seminars to introduce technical staff to the capabilities of the Laboratory's fabrication facilities. Called "Build Anything," the series covered mechanical fabrication techniques, electronics, assembly and integration of systems, and test procedures. A special session on rapid prototyping was conducted by Dr. Andrew "Zoz" Brooks, formerly of MIT's Media Lab and a co-host on the Discovery Channel's *Prototype This!* show.

The Training and Development Program sponsored courses in MATLAB techniques, management techniques, and scientific and technical writing. Division and staff seminars on current research continued to be presented every week, and the Technology Office hosted a number of special seminars on novel concepts such as cyber attacks, robotics, nanofluidic devices, MIT's Intelligence Initiative, and close-in data collection.

In addition, the Laboratory encourages its staff to pursue advanced education. 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. This year, under the Lincoln Scholars Program, one staff member earned a doctorate and 11 earned master's degrees, primarily in electrical engineering and computer science. The Laboratory's Graduate Education Committee coordinates two distance learning programs, a master's degree program in information technology from Carnegie Mellon University, and a master's in information sciences from Pennsylvania State University. This year, seven staff members completed the Carnegie Mellon degree program; currently, four people are enrolled in the Carnegie Mellon program and three in the Penn State program. Additionally, 14 Lincoln Laboratory staff members completed master's degrees and six completed doctorates at area universities.

## Technical Program Highlights

Research at the Laboratory focuses on national security problems in diverse areas: tactical and intelligence, surveillance and reconnaissance systems; air and missile defense; space situational awareness; biological-chemical 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 FAA, NASA, and NOAA. A principal activity in support of the Laboratory's technical mission is the development of components and systems for experiments, engineering measurements, and tests under field operating conditions.

During 2009–2010, the Laboratory worked on approximately 500 sponsored programs ranging from large-scale hardware projects to small seedling initiatives. Notable highlights for each mission area, as well as future directions, are listed below.

### Space Control

#### *Principal FY2010 Accomplishments*

Work continued on the Haystack Ultrawideband Satellite Imaging Radar project, an upgrade of the Haystack radar to W-band (92–100 GHz) to enable inverse synthetic aperture radar imaging of satellites in low Earth orbits with much higher resolution than possible with the current X-band radar (see figure 3). The antenna design has been completed, and the Haystack antenna radome has been uncapped to allow for installation of the new antenna surface.

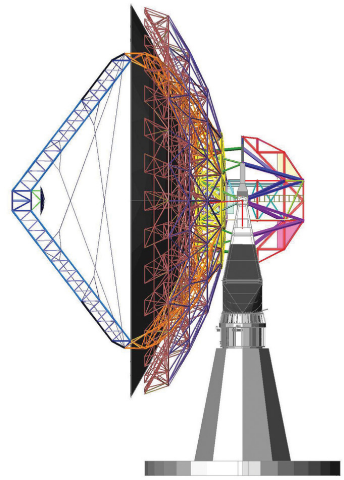

*Figure 3. Artist's rendition of the HUSIR antenna.*

The Extended Space Sensors Architecture (ESSA), an Advanced Concept Technology Demonstration and the test bed and development vehicle for bringing space situational awareness (SSA) into the net-centric realm, has had several deliveries and demonstrations with the Joint Space Operations Center.

Lincoln Laboratory is providing critical technical support to the development of NOAA's future Geostationary Orbiting Environmental Satellite. The focus is on improving the design of new flight instruments.

The future Air Force Space Fence system will require new capability for dedicated, timely, uncued detection and tracking of small objects in low (primary) and medium (secondary) Earth orbits. The Laboratory is defining system requirements and developing a performance evaluation system.

### Future Outlook

Space Control activity will move from large-scale sensor development toward information extraction, integration, and decision support. The challenges will be to incorporate the widest possible set of data and to automate the process of generating customized actionable products for a wide range of users. Operator and developer acceptance of ESSA is critical to evolving to a machine-to-machine-driven SSA capability that can respond within the timelines required to support survivability efforts.

Lincoln Laboratory is currently pursuing several initiatives in the Space Control area. Potential projects include the following:

- A small-aperture space-based space surveillance system to provide wide-area search of the geosynchronous belt every 90 minutes
- Bistatic and multistatic radar technology and techniques for fusing radar and optical imagery for space-object identification
- Climate-change monitoring that will be conducted by assessing the utility of using very-long-wave infrared radiation for space-based sensing and by exploiting a historical 30-year database of satellite sounding data to evaluate climate trends

## Air and Missile Defense Technology

### *Principal FY2010 Accomplishments*

A combined ballistic missile defense (BMD) and space situational awareness concept demonstration was carried out at the Reagan Test Site in the Marshall Islands and the Lexington Space Situational Awareness Center. The demonstration showed how net-centric services can perform real-time brokering and control of sensors between the BMD and space missions and highlighted key net-centric technologies, including sidecars, services, data exposure, and machine-to-machine tasking. Future demonstrations will extend into the intelligence, surveillance, and reconnaissance domain. The Laboratory has been working on the development of net-centric, service-oriented software and hardware architectures. Sidecars (adjunct processors that add capability while not interfering with other sensor processors and software) are a key enabling technology for this effort.

Capabilities at the Reagan Test Site continue to be expanded. The command-and-control capability at the mission control center and the optical sensors are being upgraded (see figure 4).

*Figure 4. Optical sensors at the Reagan Test Site on Kwajalein Atoll in the Marshall Islands are being upgraded to an all-digital system.*

An initial next-generation radar open systems architecture was completed and integrated into several operational sidecars for ballistic missile test and intelligence data collections. The software utilizes a network-centric middleware layer to allow rapid integration of new technologies and remote sensor control and monitoring. The software architecture is being further developed as a data and signal processing system for network-centric phased-array radars.

The Laboratory worked with the Missile Defense Agency and the Office of the Secretary of Defense to define technical architectures for an integrated homeland air and missile defense.

### *Future Outlook*

Lincoln Laboratory is strengthening its air defense mission area, with a focus on the needs of the armed services and homeland air defense. Current major growth areas include new electronic warfare and radar capabilities for the Navy and prototype architectures and technologies for homeland air defense.

The Laboratory continues to have a significant role in characterizing the capabilities and limitations of deployed ballistic missile defense components and in helping to develop, refine, and verify tactics, techniques, and procedures to optimize performance. Areas of particular focus are system-wide tracking and discrimination, system-level testing, and advanced counter-countermeasure techniques.

## Communications

### *Principal FY2010 Accomplishments*

The Laboratory built a high-data-rate waveform for airborne ISR readout over the Wideband Global SATCOM system, performed over-the-air testing, and transferred the design to industry.

The Laboratory designed a terminal that will be flown on a lunar orbiter to demonstrate laser communications and ranging (see figure 5).

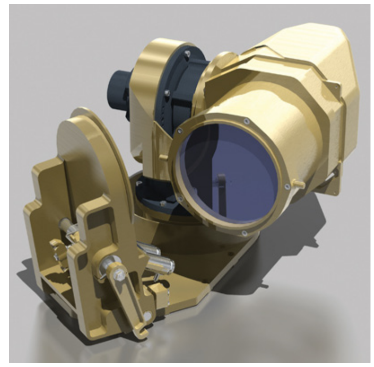

*Figure 5. Artist's rendition of the terminal that will be used for laser communications on the NASA satellite scheduled for lunar orbit in 2012.*

High-data-rate laser communications were demonstrated by using a high-efficiency superconducting, photon-counting detector-based receiver over a 1.7-km free-space link.

Lincoln Laboratory extended the capabilities of the Lincoln Adaptable Real-time Information Assurance Testbed (LARIAT) cyber test and evaluation environment, increasing the scope and fidelity of large-scale environment emulation and further automating range operations. LARIAT was deployed on national ranges in support of exercises and evaluations.

Speech systems for forensic speech processing were extended to include state-of-the-art noise suppression, speech enhancement, and speaker comparison tools.

### *Future Outlook*

Laser-communication technology development efforts will continue to enable increased data rates and improved sensitivities in high-performance systems.

The development, deployment, and evaluation of advanced cyber tools will continue. These efforts will help to evaluate and improve the robustness of future DoD systems.

The Laboratory will enhance the Net-Centric Toolkit, a collection of services that focus on enabling cross-mission interoperability of advanced sensor and command-and-control systems.

## Intelligence, Surveillance, and Reconnaissance Systems and Technology

### *Principal FY2010 Accomplishments*

Two prototype sensors for future surveillance and reconnaissance aircraft were built to detect a broad set of target signatures. These systems consist of broadband antenna arrays, high-performance signal processors, and specialized signal processing algorithms. Prototype sensors (see figure 6) were demonstrated on a Twin Otter airplane.

In a major step toward establishing a service-oriented net-centric ISR testbed at the Laboratory, a demonstration of sensor and command-and-control integration was conducted and involved representative components of homeland air defense, air traffic control, and maritime ISR.

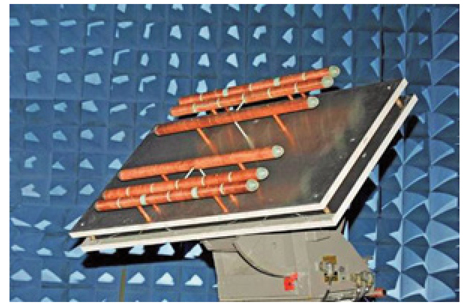

*Figure 6. New radio frequency sensing capabilities, such as this wideband planar antenna, were prototyped on a Twin Otter airplane.*

Lincoln Laboratory developed passive sonar adaptive beamforming algorithms for submarine bow sphere arrays. This work demonstrated significant detection improvements in cluttered environments, and the signal processing is transitioning into the US Navy submarine fleet.

The Laboratory developed radar modes and associated signal processing for enhanced ground moving target detection. An initial discrimination architecture to distinguish between different target types was shown to be effective with recorded experimental data. This technology is being integrated into a real-time processor for an unmanned aircraft radar.

### *Future Outlook*

Lincoln Laboratory is developing an imager, processing algorithms, and processor technologies to improve the capabilities of persistent electro-optical systems.

A net-centric ISR architecture testbed is being developed to include space and airborne ISR assets, sensor exploitation, and decision support as part of a multi-intelligence demonstration and technology development capability.

Laboratory researchers are implementing graph-based exploitation algorithms on high-performance computing architectures, including large-scale "clouds" of commodity processors, and are developing new computing architectures to enable the processing for these algorithms to run on small-form factors.

## Advanced Electronics Technology

### *Principal FY2010 Accomplishments*

With respect to the development of photon-counting detectors, Lincoln Laboratory has made advances in extending photon-counting avalanche photodiodes to shortwave and midwave infrared wavelengths, as well as in improving reliability and increasing array size, detection efficiency, and other critical performance parameters.

High-performance, superwideband compressive receivers have been used in increasingly sophisticated airborne demonstrations, and substantial improvements have been made in performance and in reducing size, weight, and power.

Following up on a successful 2008 feasibility demonstration of standoff detection of trace chemical explosives via ultraviolet fluorescence, the Laboratory has made progress in understanding the impact of clutter sources on the technique.

Through the initiation of a new multiproject run, the Laboratory is investigating the application of its unique three-dimensional integrated circuit technology to a broader range of advanced digital and mixed-signal circuits (see figure 7).

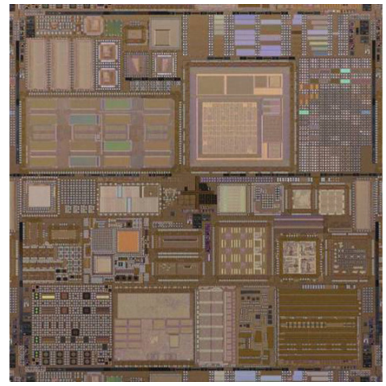

*Figure 7. The many experimental circuits fabricated in the three-dimensional multiproject wafer run.*

### *Future Outlook*

The exploitation of advanced radio frequency (RF) structures, such as microelectromechanical (MEM) capacitive switches and compressive filters, in combination with digital processors, will push innovation into broadband receivers for important new applications. The transition to foundry production of the recently demonstrated low-loss, long-life, fully packaged MEM switch will accelerate the deployment of compact, reconfigurable RF systems.

The scope of applications that could use Geiger-mode single-photon detection technology continues to expand, ranging from laser radar to communications and passive low-light-level imaging. These applications require not only improved avalanche photodiode arrays at a variety of wavelengths but also increasingly complex per-pixel readout electronics. Significant development work is needed to better understand Geiger-mode avalanche photodiode arrays, to improve their reliability, and to characterize their performance in demanding environments.

A three-year recapitalization of the Microelectronics Laboratory is under way. The upgraded facility will enable improved wafer processing and advanced packaging.

## Homeland Protection

### *Principal FY2010 Accomplishments*

Work on the Imaging System for Immersive Surveillance, a next-generation urban video surveillance system providing tactical and forensic 360-degree situational awareness (see figure 8), includes deployment and testing of the system at a major urban airport, as well as the creation of a higher-resolution, 240 Mpixel sensor.

A successful demonstration of an air surveillance system built for the Navy and based on the Enhanced Regional Situation Awareness architecture was performed in Norfolk, VA. This demonstration is a model for the deployment of similar air security systems in the United States.


*Figure 8. The ISIS display provides 360-degree situational awareness as well as zoomed-in views of a location under surveillance.*

In support of the Army and the Department of Homeland Security, Lincoln Laboratory developed ground surveillance concepts and site installation plans for wooded, lake, and river environments on the northeast US border. The Laboratory is testing the ability of unattended seismic, acoustic, and infrared sensors to detect walkers and vehicles in a wooded border site.

The Laboratory established a partnership with the California emergency response community to pursue prototyping a situational awareness system to support disaster response. A demonstration of the system took place in fall 2009.

### Future Outlook

Over-the-horizon radar and airborne systems are emerging as promising means to achieve an integrated air, land, and maritime surveillance architecture for homeland defense and security. Lincoln Laboratory will lead in-depth modeling and design activities to guide DHS and DoD investment and implementation decisions.

Rapid high-discrimination biotriggers and low-cost biodetectors will be transitioned to DoD and DHS users.

The Laboratory will pursue screening concepts at border points of entry for chemical, biological, and explosives hazards.

Lincoln Laboratory plans to expand the installation and evaluation of border surveillance sensors, including advanced infrared and low-light imagers and trip wires, ground moving target indication radars, and tunnel intrusion and small unmanned aerial systems.

## Tactical Systems

### *Principal FY2010 Accomplishments*

To evaluate the capabilities and limitations of infrared sensors and seekers in supporting beyond-visual-range passive air-to-air engagements, the Laboratory is performing systems analysis, developing detailed models of infrared search-and-track systems and imaging infrared missile seekers, and conducting laboratory and captive-carry testing of various surrogate systems.

A prototype robot-mounted sensor for use by explosive ordnance disposal teams was successful in continental US (CONUS) demonstrations and in Army capabilities and limitations testing (see figure 9). The prototype has been transitioned to the field and is undergoing operational tests overseas.

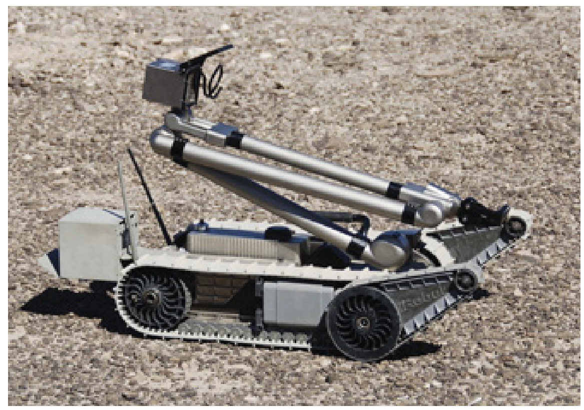

*Figure 9. Lincoln Laboratory is working with industry to integrate Laboratory-developed sensors on robots, such as this PackBot.*

An advanced airborne signal intelligence capability was demonstrated in local test flights and in a CONUS operational exercise. This capability leverages receiver hardware, antennas, and detection algorithms developed by the Laboratory over the past several years. Ground-vehicle-integrated and man-portable versions of the system were also rapidly developed for the military and are now being transitioned to operational use.

Lincoln Laboratory began the development and transition of two airborne sensor systems for use in a quick-reaction intelligence, surveillance, and reconnaissance capability. Both systems will be integrated on an Army aviation asset.

### *Future Outlook*

The Laboratory will support the US Air Force's continued efforts to improve the acquisition and employment of various tactical air and counterterrorist systems by helping to provide an understanding of the operational utility and limitations of advanced technologies.

Sidecar systems will be developed for capabilities-based assessments of threatening RF systems. A common system architecture will be used to evaluate signal processing and electronic protection upgrades for surveillance, target acquisition, and fire-control radars.

The current counterterrorism testbed, which supports most of the advanced signal intelligence capabilities developed for counterterrorism applications, will be expanded. The enhanced testbed will take on a greater software-defined sensor role and will be used to prototype additional advanced capabilities. The flexibility of this testbed is expected to enable the rapid demonstration of new capabilities developed in response to time-critical needs.

## Air Traffic Control

### *Principal FY2010 Accomplishments*

Under development are a Tower Flight Data Manager for future air traffic control towers and the associated decision support capability, the Arrival/Departure Management Tool. This project supports FAA's Next Generation Air Transportation System through development of the terminal area information exchange architecture, electronic flight data management capability, and integrated arrival/departure and surface traffic management (see figure 10).

To support the FAA's acquisition of a national Automatic Dependent Surveillance–Broadcast (ADS-B) system, the Laboratory analyzed surveillance requirements and radar/ADS-B fusion algorithms needed for air traffic control at key ADS-B sites. This work included analysis of wide-area multilateration (locating aircraft by computing the time difference of arrival of multiple radio signals) as a backup for ADS-B.

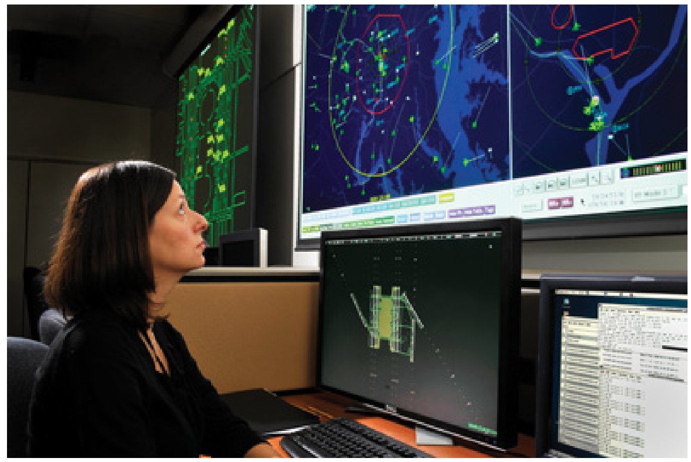

*Figure 10. The Laboratory's air traffic management lab supports development of capabilities and tools for managing flight data.*

The Runway Status Lights system continues successful operation at Dallas/Fort Worth International Airport, where a new capability was added and evaluated: the Final Approach Runway Occupancy Signal, which provides warnings to pilots on final approach that the runway ahead is occupied. Runway Entrance Lights and Takeoff Hold Lights have also been installed and evaluated at Los Angeles International Airport. The system is being tested at Boston Logan International Airport.

### *Future Outlook*

Lincoln Laboratory is assuming an increasingly influential role in the definition and development of FAA's future System-Wide Information Management architecture that will encompass surveillance, weather, and flight planning/flight event data exchange; decision support applications; and efficient sharing of information among decision makers involved in operating the National Airspace System.

The Laboratory's thunderstorm forecasting capabilities and associated decision support tools will play an increasingly important role in alleviating delays associated with severe weather. The Route Availability Planning Tool, a system designed to expedite departures during convective weather, will be deployed as a prototype at three additional airports and will eventually be incorporated into the FAA's national Traffic Flow Management System.

A program to develop air traffic control tower surveillance capabilities, automation platforms, and decision support services will improve safety and efficiency at conventional, on-airport staffed towers and may permit migration of air traffic control services to remote locations at some smaller airports.

## Collaboration with the MIT Campus

A variety of initiatives supported by the MIT campus and Lincoln Laboratory promote research collaborations, foster knowledge exchange, and enhance professional development. In addition, the exceptional MIT alumni who join the Laboratory increase the opportunities for establishing joint projects. This year, 29 MIT alumni became staff members at Lincoln Laboratory.

Below are some of the cooperative programs that strengthen research at both institutions.

### Integrated Photonics Initiative

A unique collaboration between Lincoln Laboratory and the MIT campus is the Integrated Photonics Initiative (IPI), a multiyear, Laboratory-funded effort that enhances the research experience of PhD candidates working on integrated photonics devices and subsystems for potential insertion into advanced communications and sensor systems. During the past year, the IPI funded three students.

### Advanced Concepts Committee

Collaborative projects with the campus are supported through the Advanced Concepts Committee. The committee provides seed funding and proactive technical and liaison support for developing advanced concepts that address high-priority national problems. These concepts may enable new systems or promote significant improvements in current practices. In 2010, the committee funded 10 projects; listed below are some representative projects to illustrate the breadth of research undertaken through this initiative (MIT researchers are denoted with asterisks):

- Passive Quantum Error Correction Using Topological Toric Codes: Analysis and Simulation (researcher: J. Cortese)
- Social Behavior Prediction Through Reality Mining (researchers: W. Campbell, G. Pickard, A. Pentland*)
- Imaging into Obscured Areas (researchers: R. Heinrichs, R. Raskar*)
- Nanofluidic DNA Ruler (researchers: C. Aguilar, R. Karnik, J. Kedzierski, T. Thorsen)

The committee also sponsors the Defense Studies Seminar Series. This year's speakers included professor Sanford Weiner, professor M. Taylor Fravel, and professor Austin Long of the MIT Center for International Studies.

### Beaverworks

In a partnership with the MIT Department of Aeronautics and Astronautics, Lincoln Laboratory undergraduate and graduate students in two courses had the opportunity to participate in a real-world project—"Beaverworks"—whose goal was to build an unmanned aircraft that would carry a sensor for measurement of ground-based antenna patterns. The Laboratory also assisted in the project by designing the payload antenna and affording the students access to its radio frequency antenna test facility. During two semesters, 40 students designed, built, and flight-tested the aircraft, which will be delivered to the Laboratory after final modifications this summer.

## Technology Transfer

Lincoln Laboratory's focus on adapting and demonstrating advanced capabilities to enhance existing systems results in important technology transfer opportunities. The mechanisms for transferring technology developed by Lincoln Laboratory to industry, academia, and government include briefings and technical publications; 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.

Delivery of hardware, software, algorithms, and advanced architecture concepts to government contractors included the following:

- Lincoln Laboratory's silicon and indium phosphide Geiger-mode avalanche photodiode (APD) technologies were transferred to US industry. Boeing, BAE, Lockheed Martin, and Northrop Grumman are among the companies using Laboratory-developed APD arrays.
- Also transferred to companies such as Northrop Grumman and Mesosystems were a low-cost bioaerosol sensor technology and microelectromechanical systems RF switch technology.
- Spherically curved, silicon charge-coupled device imager technology has been used in the focal-plane arrays for the Defense Advanced Research Projects Agency's Space Surveillance Telescope.
- The Laboratory began transfer of fully depleted silicon-on-insulator complementary metal-oxide semiconductor process technology to an agency making critical electronics components available to the military.

Working through the MIT Technical Licensing Office, the Laboratory was awarded 10 US patents between July 1, 2009, and June 30, 2010. One of these patents was for the Multi-element Optical Detectors with Sub-wavelength Gaps technology, which was developed by researchers at Lincoln Laboratory and the MIT campus and won the first MIT Lincoln Laboratory Best Invention Award (as described above).

## Dissemination of Technical Knowledge

The dissemination of information to the government, academia, and industry is one of the principal activities fulfilling Lincoln Laboratory's technical mission. Wide dissemination of technical information is achieved through annual technical workshops and seminars hosted at Lincoln Laboratory. These events bring together members of technical and defense communities to share technology advances, to discuss innovative concepts, and to foster a continuing dialogue that strengthens technology development and provides direction for future research. The following events were held this year:

- High Performance Embedded Computing Workshop
- Intelligence, Surveillance, and Reconnaissance Systems and Technology Workshop
- Homeland Protection/Bio-Chem Defense Systems Workshop
- Space Control Conference
- Air Vehicle Survivability Workshop
- Ballistic Missile Defense Technical Seminar
- Cyber and Netcentric Workshop

In addition, the Laboratory presents technical courses for military officers, DoD civilians, and defense subcontractors. These include:

- Defense Technology Seminar
- Introduction to Radar Systems
- Anti-tamper Policy, Technology, and Application
- Courses in ballistic missile defense, net-centric and cyber operations, and space technology and policy (offered in a joint effort with Tufts University at the Naval War College in Newport, RI)

### Publications

Knowledge dissemination is also achieved through the many venues in which Lincoln Laboratory researchers publish. The technical staff publish articles in peer-reviewed journals and present at national technical conferences such as the IEEE Military Communications Conference and the annual meeting of the IEEE Lasers and Electro-Optics Society. The Laboratory publishes the *Lincoln Laboratory Journal*, which contains comprehensive articles on current major research and journalistic pieces highlighting novel projects.

### Educational Partnerships with Universities

Lincoln Laboratory continues to promote technical education and knowledge exchange through partnerships with local universities. This year, under the sponsored research program, Lincoln Laboratory hosted 62 graduate and 61 undergraduate students. Under collaborative programs with MIT, the Laboratory recently hosted six VI-A MEng students, seven Undergraduate Research Opportunities Program students, and three Undergraduate Practical Opportunities Program students. In an ongoing partnership with the Worcester Polytechnic Institute, 14 seniors are beginning their major qualifying projects at Lincoln Laboratory in August.

## Diversity and Inclusion

Recent initiatives are fostering an inclusive workplace that leverages and supports the talents and perspectives of the Laboratory's staff. Recruiting at a broader range of colleges and universities, new programs in mentoring, a more comprehensive new employee orientation, and flexible work options are contributing to the hiring and retaining of a more diverse workforce. New ventures are also enhancing the environment of inclusiveness.

### Lincoln Laboratory New Employees Network

The Lincoln Laboratory New Employees Network helps new employees with their transition to the Laboratory and the region. Members serve as resources for one another, providing information and insights on the Laboratory, local services, and professional development activities.

### Lincoln Laboratory Technical Women's Network

The mission of the Technical Women's Network is to promote the recruitment, retention, and achievement of women technical staff at Lincoln Laboratory. The group provides professional development opportunities, sponsors a mentoring program, and encourages participation in the Laboratory's recruiting efforts.

## Community Outreach

The Lincoln Laboratory Community Outreach (LLCO) was established to encourage community service and promote education in science and engineering.

Recognizing the importance of motivating young people to pursue careers in science, technology, engineering, and mathematics (STEM), LLCO focuses substantial attention on educational outreach. This year, Lincoln Laboratory formed a collaboration with the National Defense Education Program in order to broaden its K–12 STEM education program.

In 2009, Lincoln Laboratory formed a partnership with the MIT Department of Engineering's Office of Engineering Outreach Programs, which runs four educational programs for middle and high school students. All four programs are designed to prepare students for postsecondary study and to encourage them to consider careers in STEM. The Laboratory sponsors students in each of the programs, provides tours of Lincoln Laboratory's unique facilities to student groups, and offers courses or presentations given by members of the Laboratory's technical staff.

Lincoln Laboratory's robotics initiative, Robotics Outreach at Lincoln Laboratory (ROLL), is in its third year. ROLL takes advantage of the popularity of robotics to interest students between the ages of 9 and 17 in technology. ROLL hosts robotics workshops at the Laboratory, sponsors teams in FIRST (For Inspiration and Recognition of Science and Technology) competitions, and provides technical mentors to local area schools and groups. The Laboratory-mentored robotics team of 11- to 13-year-olds participated in the FIRST LEGO League Massachusetts regional competition in November, placing first overall and 10th in robot design out of more than 60 teams. The FIRST Technical Challenge team of high school students again competed in the FIRST Finals in Atlanta, placing 13th out of 50 teams (see figure 11).

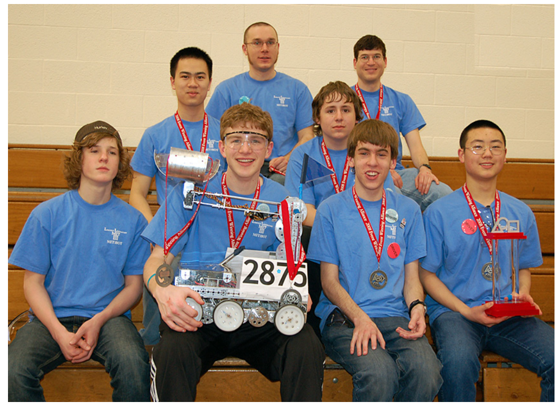


*Figure 11. The Laboratory-mentored FIRST Technical Challenge team, MITiBot, placed in the semifinals of the FIRST World Championships. The mentors are in the back row.*

During the 2009–2010 school year, more than 3,000 K–12 students, parents, and teachers attended science demonstrations given by Laboratory technical staff through the Science on Saturday program. This year, demonstrations were offered on lasers and optics, how computers work, liquid nitrogen's properties, and heat. Technical staff volunteers also gave classroom presentations on science and engineering to students in local elementary and middle schools. Since the beginning of the classroom presentation program, more than 6,000 students have enjoyed these hands-on demonstrations.

As a partner in the regional Leadership Initiatives for Teaching and Technology program, which provides summer employment opportunities for math and science teachers, Lincoln Laboratory is employing three Massachusetts high school teachers in summer 2010. Math teachers from high schools in Marlborough and Hudson and a physics teacher from Dracut High School are working with Laboratory researchers to analyze and evaluate data.

The Laboratory's community service program continues to thrive and grow. The ongoing campaign to collect and mail food, toiletries, and books to US soldiers overseas resulted in 215 "care" packages being sent to 37 US troops in Iraq and Afghanistan. A new project, the Memory Walk for the Alzheimer's Association, raised more than $9,000 to provide services to Alzheimer's patients in Massachusetts and New Hampshire. During the winter, the Laboratory added a coat drive and the Hannah's Socks drive to its charitable programs; 500 coats and 1,930 pairs of socks were collected for distribution to needy children and adults. LLCO again facilitated participation in the Bike and Hike the Berkshires event that raises funds for the Multiple Sclerosis Society; the more than $15,000 raised by the bike and hike team was its largest donation to date, making the Laboratory the second-leading fund-raiser in the event.

## Summary

Demand for Lincoln Laboratory's research remains strong. Current programs cover a broad spectrum, from fundamental investigations to developmental engineering, and the sources of sponsorship are diverse. Emerging national concerns are leading to opportunities for research and development in areas such as tactical systems, biological and chemical sensing, cyber security, net-centric architectures, integrated sensing, and decision support technologies. Prototyping efforts experienced significant growth, and the expansion in this area has been valuable to the recruitment of talented technical staff members. The Laboratory continues to emphasize technology transfer. Charitable giving activities are providing needed resources to local communities and organizations, and the educational outreach program is growing, particularly in its reach to students in underserved communities. Ongoing improvements to support engineering, administration, and infrastructure sustain the Laboratory's ability to achieve its mission. In conclusion, Lincoln Laboratory is well positioned to take on the challenges and responsibilities inherent in its mission of service to the nation.

**Eric D. Evans**
**Director**

*More information about Lincoln Laboratory can be found at http://www.ll.mit.edu/.*