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.

As the Laboratory celebrates its 60th anniversary in 2011, it is positioning itself to meet new challenges presented by the evolving needs of the nation and its military forces. Cyber security, so critical in this era of networked, real-time information, has been designated a new mission area. Improvements to the Microelectronics Laboratory and the Engineering Division's facilities are enabling advanced component and system development. Rapid prototyping efforts are expanding, and the Laboratory is investigating how its expertise in sensing and communication technologies may be applied in autonomous systems and quantum information sciences.

For the federal fiscal year 2011, Lincoln Laboratory is projected to receive approximately $896 million that will support the efforts of approximately 1,700 professional technical and managerial staff and 2,000 support personnel and subcontractors; outside procurement will exceed $313 million. While most of the research is sponsored by the 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). Lincoln Laboratory also carries out noncompetitive research with industry under approved Cooperative Research and Development Agreements and other collaborative activities with academic institutions.

On April 1, 2010, the Department of Defense awarded a five-year reimbursement contract option to MIT for the operation and management of Lincoln Laboratory as 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, 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 (Figure 1). Sponsors' interest in conducting research and development of more complex, integrated systems has raised the level of collaboration between divisions. In addition, service departments, as providers of standardized support, and the Safety and Mission Assurance 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 the Laboratory's Structure

Last year, the Laboratory made a number of organizational changes during its restructuring of divisions to align research and development with areas of increasing relevance to national security: homeland protection, cyber security, tactical systems, and intelligence, surveillance, and reconnaissance (ISR). This year has been one of maturing programs in these areas, continuing to strengthen core programs, and improving the physical and information technology (IT) infrastructures that support the technical work.

In June 2011, Charles W. Maxson was appointed the head of the Information Services Department. He will be leading efforts to enhance IT services.

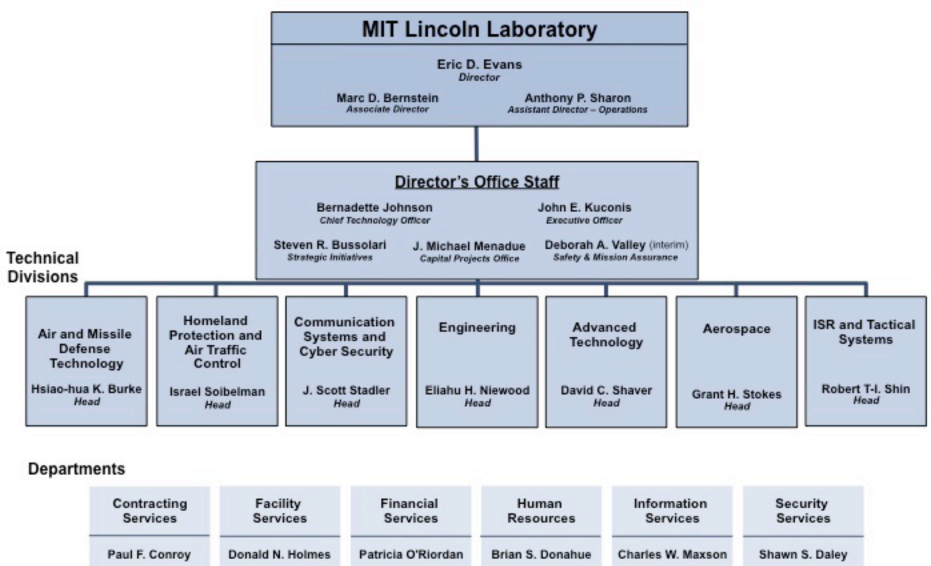

Figure 1. Lincoln Laboratory's organizational structure.

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 percent 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 3,711, with 1,682 technical staff, 1,424 support staff (including technical support personnel), and 605 subcontractors.

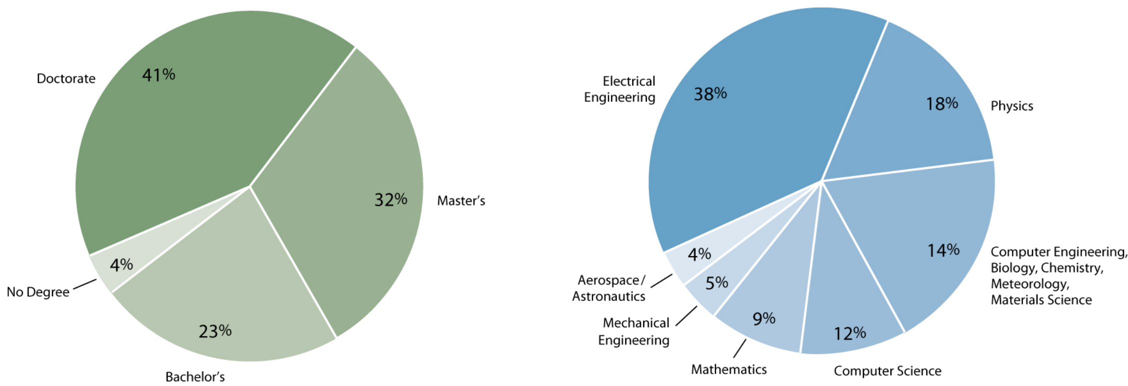

Figure 2. Composition of professional technical staff by academic degree (left) and academic discipline (right).

Staff Honors and Awards

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

- Dr. Eliahu H. Niewood was appointed chairman of the Air Force Scientific Advisory Board.
- Dr. Mohamed D. Abouzahra was named a fellow of the Institute of Electrical and Electronics Engineers (IEEE).
- Dr. Jeremy B. Muldavin was named a 2011 IEEE Microwave Theory and Techniques Society Outstanding Young Engineer.
- Dr. David J. Ebel and Dr. William D. Ross received MIT Lincoln Laboratory 2010 Technical Excellence Awards.
- Dr. Thomas F. Quatieri and Tianyu T. Wang received the MIT Lincoln Laboratory Best Paper Award for "High-Pitch Formant Estimation by Exploiting Temporal Change of Pitch," published in IEEE Transactions on Audio, Speech, and Language Processing.
- Dr. Robert K. Reich and Harry R. Clark Jr. received the MIT Lincoln Laboratory Best Invention Award for development of a patent-pending liquid crystal thermal imager.
- Nadya T. Bliss, assistant leader of the Embedded and High Performance Computing Group, and Dr. Timothy M. Hancock, a technical staff member in

the Analog Device Technology Group, received the first MIT Lincoln Laboratory Early Career Technical Achievement Awards.

- Dr. Jonathan C. Herzog was awarded the IEEE Computer Society Meritorious Service Award.
- Dr. Kenneth M. Chadwick received the US Army Outstanding Civilian Service Award.
- David P. Conrad received the Missile Defense Agency Director's Pinnacle Award.

R&D 100 Awards

Four Lincoln Laboratory technologies were named 2011 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 four distinct areas of research:

- Airborne Ladar Imaging Research Testbed (ALIRT): an airborne laser radar that rapidly collects high-resolution three-dimensional imagery of wide-area terrains. The ALIRT system was developed by a team from the ISR Systems and Technology, Tactical Systems, Engineering, and Advanced Technology divisions led by program manager Robert Knowlton.
- Multifunction Phased Array Radar (MPAR) Panel: panels of phased arrays exploit dual polarization and digital beamforming to provide efficient radar detection and tracking of aircraft and weather targets. Under FAA sponsorship, the MPAR panel was jointly developed by Lincoln Laboratory and M/A-COM Technology Solutions. The developers from the Laboratory, members of the ISR Systems and Technology, Tactical Systems, Homeland Protection, and Air Traffic Control divisions, were led by program manager Jeffrey Herd.
- Parallel Vector Tile Optimizing Library (PVTOL): a real-time signal processing library that enables cross-platform portability of programs without sacrificing high performance. Led by James Daly, a team from the Laboratory's Embedded and High Performance Computing Group developed PVTOL.
- Pathogen Analyzer for Threatening Environmental Releases (PANTHER) Bioaerosol Identification System: a highly sensitive sensor that uses genetically modified white blood cells to rapidly detect and identify pathogens and toxins. PANTHER and the underlying CANARY (cellular analysis and notification of antigen risks) technology were developed by a team from the Advanced Technology, Homeland Protection, Air Traffic Control, and Engineering divisions. James Harper, Joseph Lacirignola, and Richard Mathews led the development of the portable PANTHER prototype.

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, as follows:

- For highly qualified candidates, the Laboratory offers the opportunity to apply to the Lincoln Scholars program, which supports the full-time pursuit of advanced degrees. The candidates accepted into the program perform their thesis research work at the Laboratory while serving as contributing members of the staff. This year, under the Lincoln Scholars program, three staff members earned doctorates and three earned master's degrees; 22 staff members are now enrolled in the program, and nine more are expected to be added in fall 2011.
- The Graduate Education Committee also 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. Currently, four people are enrolled in the Carnegie Mellon program and three in the Penn State program; two candidates have been accepted into the Penn State program for fall enrollment.
- The technical education program offers semester-length courses taught by Lincoln Laboratory technical staff or by outside experts, often professors from MIT. The 2010 fall/winter session included the following courses: Introduction to Robotic Systems, Understanding and Using Digital Signal Processing, and Introduction to Radar Systems, Part II.
- The professional and leadership development program sponsors courses in leadership techniques, project management, and scientific and technical writing.
- Computer training in common software applications (Word, PowerPoint, Excel, Illustrator, Photoshop, etc.) and in technical software (MATLAB, Simulink, VxWorks, etc.) is offered onsite throughout the year.

The Technology Office coordinates an extensive program of seminars presented at the Laboratory by leading researchers from universities and industry. The office expanded the number and range of seminars this year; the talks addressed diverse topics such as visual processing, ultrasound image processing for robotic cardiac surgery, information diffusion in networks, rapid prototyping tools, and photonics.

The Laboratory's library, in collaboration with the MIT Libraries, makes a variety of online learning opportunities available to Laboratory staff:

- IEEE eLearning Library, which offers nearly 200 online courses
- MIT seminars accessed through MITWorld
- MIT Microsystems Technology Laboratories (MTL) seminars accessible through the MTL web page

In addition, division and staff seminars on current research are presented every week, and the service departments offer courses and training specific to their areas. The revitalized internal website provides collaboration tools that enable special interest groups, such as the Satellite Toolkit Users Group, to share information.

Diversity and Inclusion

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

- The establishment of four new mentorship programs was announced in early 2011. These new mentoring programs are being phased in during 2011–2012. The programs are designed to provide employees with support during different stages of their careers.
- New Employee Guides: introduction for new employees to their groups, divisions, and departments
- Early Career Mentoring: six-month, one-on-one mentoring for professionals starting out in their careers
- Circle Mentoring: small, often topic-specific, discussion groups led by experienced employees
- New Assistant Group Leader Mentoring: mentoring of a new assistant group leader by an experienced group leader

Also, the Hispanic/Latino Network, which provides a supportive social environment for employees and raises awareness of the Hispanic culture, was founded in 2010–2011.

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 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 2010–2011, 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 Accomplishments

Fabrication of the mirrors and corrector optics for the Space Surveillance Telescope was completed. The telescope enclosure at the Atom Site on White Sands Missile Range in New Mexico was also completed, and the telescope mount gimbal was installed at the site in 2010 (Figure 3). The telescope achieved first light in February 2011.

Figure 3. The Space Surveillance Telescope in its enclosure on North Oscura Peak in New Mexico.

The Millstone Hill Radar supported dozens of domestic and international space launches. The Haystack Long-Range Imaging Radar and the Haystack Auxiliary Radar provided additional characterization information on these launches. All three radars at the Lincoln Space Surveillance Complex were used by Laboratory analysts to provide timely damage assessments on rare satellite breakup events.

Under Air Force sponsorship, Lincoln Laboratory is developing the Haystack Ultrawideband Satellite Imaging Radar (HUSIR), 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. The major subassemblies of the new HUSIR antenna, including the back structure, the quadrapod, and the steel transition structure, have been integrated and staged at the Haystack site.

Studies and experiments with sensor hardware, processing software, and operational techniques were conducted to evaluate the benefits of new technology to US government sponsors. This work forms the basis of designing a comprehensive space situational awareness architecture for the nation.

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.

Sensor systems under development will bring new capability to the Space Control mission area. These systems include Space-Based Space Surveillance (block 10), the Space Surveillance Telescope, and HUSIR. Considerable time and effort will be required to fully assess the information available from the new sensors and make it most useful to operators.

Emerging technical areas include advanced radar development, radar surveillance, space-object identification, electro-optical deep-space surveillance, collaborative sensing and identification, fusion, and processing.

Air and Missile Defense Technology

Principal Accomplishments

At the direction of the Navy Program Executive Office for Integrated Warfare Systems, the Laboratory is designing, implementing, and testing a new electronic ship decoy system for future fleet defense against advanced antiship missiles. Prototype subsystems were designed and tested.

Figure 4. The modernized mission command-and-control center at the Reagan Test Site.

Laboratory scientists and engineers served as leads for a program that will transform the Reagan Test Site (RTS) on Kwajalein Atoll, Marshall Islands, from a locally operated range to one operated remotely from sites in the continental United States. Upgrades to the software, sensors, and communications links enable these distributed operations. The command-and-control center developed by Lincoln Laboratory has been certified for use as the RTS's mission control system (Figure 4).

A high-fidelity radar cross-section signature-modeling methodology and toolset known as the Augmented Point Scattering Model is being integrated into community-standard threat data packages that will be used in planning ballistic missile defense (BMD) tests.

Development continued on the XTR-1 mobile instrumentation radar to provide key data during BMD tests that are beyond the reach of ground-based instrumentation. Testing was accomplished at the Laboratory's Firepond ground test site in Westford, MA, to validate key requirements. With the Laboratory's assistance, the radar is being integrated onto a ship for operations in 2011.

Future Outlook

In response to the existing and growing regional missile threat, Lincoln Laboratory continues to be a key member of the integrated test process that validates both the Ballistic Missile Defense System and its components.

The Laboratory will continue to execute and develop programs in electronic warfare, with a particular focus on Navy applications. These programs include the development of advanced electronic countermeasures for defense against antiship missiles and advanced electronic protection capabilities for airborne radar systems.

By leveraging prior efforts in open system architectures and distributed radar command and control, the Laboratory has developed a model of a plug-and-play test bed that has been demonstrated in live-fire mission tests involving missile defense, space situational awareness, and cyber components.

Communication Systems

Principal Accomplishments

The Laboratory completed lab and field testing of a high-data-rate waveform for airborne ISR readouts over the Wideband Global SATCOM system. This waveform will be transferred to airborne ISR platforms.

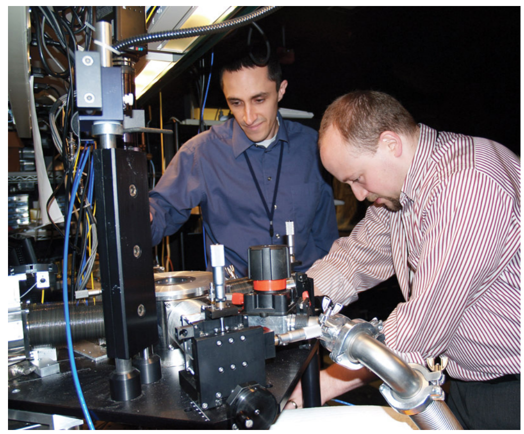

Figure 5. Eric Dauler (left) and Jamie Kerman are two of the developers of the superconducting nanowire single-photon detector.

The Laboratory developed and distributed high-fidelity behavioral models of the mobile ad hoc networking waveforms that will be used in next-generation tactical radios. The models can be used to evaluate and visualize large-scale mobile ad hoc networks in real time.

Laboratory researchers demonstrated the potential for secure quantum key distribution at rates of 1.85 megabits per second over more than 100 km of fiber, exceeding previous results by two orders of magnitude. The demonstration used the Laboratory's high-efficiency, high-speed, low-dark-count-rate superconducting nanowire single-photon detectors (Figure 5) and leveraged its expertise in developing high-sensitivity classical differential-phase-shift-keying optical communication systems.

Lincoln Laboratory successfully demonstrated error-free data transfer over an air-to-ground laser communications (lasercom) link, operating at 2.67 gigabits per second over 60-km ranges, from an aircraft at 12 kft to a ground terminal. The airborne lasercom system, which operates at eye-safe power levels from a small (~2.5 cm) aperture, employs spatial and temporal diversity techniques to mitigate signal fading caused by atmospheric turbulence.

Installation and checkout of the Advanced Extremely High Frequency (AEHF) interim command-and-control terminals were completed. The Laboratory supported the preparations for the launch and calibration of the first AEHF satellite.

Future Outlook

The development of architectures and technologies to provide new capabilities for the space, ground, and airborne layers of DOD and NASA communications infrastructure will continue.

Lincoln Laboratory will continue to perform large-scale demonstrations of enabling technologies for net-centric operations. These demonstrations will combine Laboratory-developed services with DOD Net-Centric Enterprise Services.

Laser communication technology efforts will focus on investigating clouds as a transmissive or reflective channel and as the space/air-to-submarine channel.

The Laboratory will extend its work on information extraction from speech and text, including extraction of entities, links, and events, and will apply that work to enhanced social network analysis and intent recognition.

Cyber Security

Principal Accomplishments

Cyber situational awareness tools were developed to display worldwide malware activity; the tools have the ability to interactively drill down to discover cities and countries that permit or actively prevent the spread of malicious code. These tools were installed into key national-level cyber-threat operations centers.

Laboratory-developed approaches to secure communications among dynamic groups of participants in a tactical environment (unmanned aerial systems and ground stations in theater) were demonstrated and are being standardized for government and commercial use.

The Lincoln Adaptable Real-time Information Assurance Testbed (LARIAT) cyber range software was restructured to include open interfaces among the system components. LARIAT is currently deployed at more than 80 DOD and contractor cyber ranges nationwide. This update will enable third-party capabilities to be easily integrated into the core system.

The Laboratory developed and deployed prototype secure operating system modules for the next-generation Army communications-on-the-move, satellite-connected prototype network node. This system will provide the Army with the capability of secure communication from moving ground vehicles.

Future Outlook

Lincoln Laboratory will analyze mission-critical systems to provide insight into operating successfully in a contested cyber domain. This work supports traditional Laboratory mission areas such as ballistic missile defense, space control, air vehicle survivability, and satellite communications.

The Laboratory will develop an open architecture for tamper-resistant embedded systems. This effort will lead to a shift away from proprietary, classified anti-tamper approaches toward open systems that are still highly secure but will reduce cost, enable reuse of components, and allow for rapid fielding.

New technologies for large-scale cyber ranges will be developed. These will include novel methods to support low- or zero-artifact instrumentation and actuation.

Intelligence, Surveillance, and Reconnaissance Systems and Technology

Principal Accomplishments

High-performance radio frequency (RF) receivers based on RF integrated circuits were shown to provide unprecedented performance (Figure 6) while consuming very little size, weight, and power—all crucial considerations for RF sensor systems applications on smaller unmanned aerial vehicles.

The Laboratory has been developing novel airborne radar techniques to detect and track ground moving targets. New radar modes using feature-based digital signal processing algorithms that exploit unique target phenomenology have been tested and shown to provide reliable target classification.

Figure 6. The Laboratory operates a mobile signal analysis capability for developing and testing new RF sensing and communication capabilities. The van (inset) is equipped with a roof-mounted broadband antenna array and significant data recording and computing hardware for collection and field data analysis.

In support of national needs for wide-area persistent surveillance, the Laboratory has continued to develop and demonstrate end-to-end systems for collection and exploitation of these revolutionary data sets. In 2010, the Laboratory flew gigapixel-class visible and infrared airborne systems coupled with onboard data processing and a ground processing toolset. The processing and exploitation systems were deployed to a forward operating location.

The Laboratory successfully demonstrated 1.3 gigabits per second wireless communication over a 75-meter link from a vehicle traveling up to 35 miles per hour. Advances in multiple-input/multiple-output communications, robust waveform design, and signal processing techniques enable extremely high-data-rate links in challenging urban environments.

A new research activity in the theory and application of graph detection algorithms was initiated, in part to develop more effective methods for discovering insurgent networks through analysis of persistent surveillance sensor data. The high computational demands of these algorithms are motivating research into new parallel computing architectures designed for the sparse matrix computations inherent to this class of algorithms.

Future Outlook

The ISR Systems and Technology mission is expected to receive increasing national investment to develop and field improved systems for irregular and conventional warfare and to provide much better integration of ISR capabilities between the armed services and intelligence agencies.

Improved sensing modes that effectively detect, classify, and geolocate individual vehicles and personnel over wide areas are needed. Research into methods for detecting the manufacture or transport of explosives and weapons of mass destruction is expected to continue.

Technologies for accessing, sharing, and visualizing large data volumes are needed, as are methods for exploiting such data with the timeliness to provide agile responses. Increasing activity in decision support technologies, distributed high-performance computing, and web-based service-oriented architectures for ISR systems is envisioned to address these needs.

Advanced Technology

Principal Accomplishments

Significant additional improvements in cryogenic Yb:YAG lasers were achieved: higher continuous wave power, demonstration of ultra-short-pulse operation, and lasers with the needed beam quality, form factor, and reliability to be usable in near-term DOD application test beds.

A decades-long goal in the laser community has been to combine the output beams of many diode lasers in order to produce an electrically efficient high-power laser source. The Laboratory demonstrated over 45 W coherent output from an array of six 20-diode modules that exploit the near-ideal beam quality of the slab-coupled optical waveguide structure invented at the Laboratory.

The Laboratory remains the only organization providing access for the DOD research community to high-density 3D integrated circuit technology. The third multiproject run was completed in 2010.

Figure 7. Microelectronics Laboratory. Upgrades in 2010–2011 provide the capability for production-class sub-90-nm processing on 200-mm wafers.

In pioneering work on graphene-on-insulator (GOI) electronics, the Laboratory reported on some of the first transistors measured on GOI material. The GOI material development was carried out jointly with researchers on the MIT campus; transistor fabrication was done in the Laboratory's Microelectronics Laboratory (Figure 7).

A new high-frame-rate charge-coupled-device (CCD) imager was demonstrated for adaptive optics. This CCD uses an output circuit that has only one-half the noise of previous adaptive-optics CCDs.

Future Outlook

Innovative thrusts for emerging DOD needs result from multidisciplinary interactions enabled by the Laboratory's competencies in imaging focal planes, silicon circuit technology using 3D integration, compressive receivers, optical lithography, diode and solid-state lasers, photonic devices, and superconductive electronics.

The scope of applications for Geiger-mode (GM) single-photon detection technology is expanding, with development of GM detectors that operate at short- and mid-wave infrared wavelengths and of "smarter" readout integrated circuits for higher-speed, lower-power photon counting.

Significant activities will continue to support both nearer-term and longer-term DOD needs for high-energy lasers. Technologies will range from cryo-cooled or slab-coupled gain media to both spectral and coherent beam combining.

Chemical and biological sensing technologies will be further advanced for biological and chemical detection of explosives, toxins, and bioagents. Mid-infrared quantum-cascade lasers promise new capabilities in infrared countermeasures and chemical sensing.

Homeland Protection

Principal Accomplishments

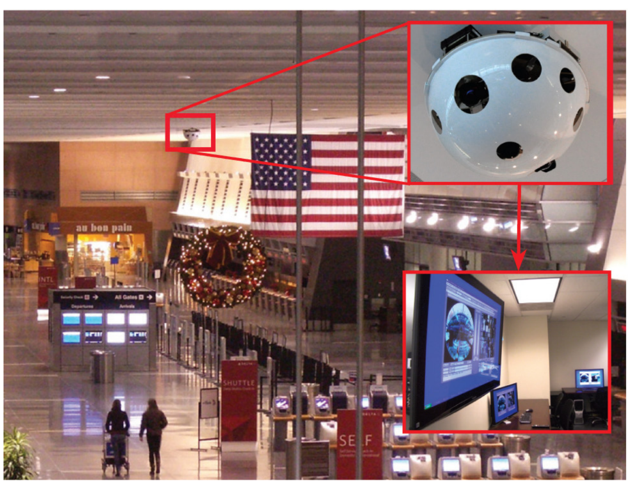

Figure 8. The Imaging System for Immersive Surveillance (top right inset) was tested at Boston's Logan International Airport. The video is displayed in real time (lower right inset).

The Imaging System for Immersive Surveillance (ISIS) consists of a custom 240 Mpixel sensor, a multi-terabyte data archive, a multiple-user video interface, and automated video exploitation algorithms for ground-based surveillance in support of critical infrastructure protection. The ISIS system, sponsored by the DHS Science and Technology Directorate, is being operationally tested in collaboration with the Massachusetts Port Authority (Figure 8).

The Laboratory has continued to support DHS in evaluating technologies for homeland air security. Key contributions included architectural development, detailed sensor and siting analysis, and risk reduction through high-fidelity modeling of emergent surveillance technologies.

A rapid biological sensing pilot system using commercial sensing technology and Lincoln Laboratory sensor fusion algorithms is being developed and will be evaluated in a subway system. If successful, this system will allow for evacuations and facility closures rapidly enough that bioagent exposures will be reduced.

Technology assessments for securing the northern and southern borders of the United States included quantifying the detection, classification, and false-alarm characteristics of a network of unattended ground sensors that utilize seismic and acoustic sensing modalities.

Future Outlook

Securing and defending US borders motivates the need for an integrated air, land, and maritime architecture. This need will spur advancements in wide-area sensors, such as over-the-horizon radar, as well as in advanced data fusion and decision support tools. Lincoln Laboratory will continue to apply its core strengths in advanced sensors, signal processing, service-oriented architecture, and rapid prototyping to enable an integrated architecture.

Analysis, development, and testing of advanced chemical and biological defense solutions will continue, with strong contributions expected in countering emerging threats.

The Laboratory will develop and assess technologies and architectures to address critical infrastructure protection. Through partnerships with local, state, and federal operational communities at airports, mass transit sites, ports, and event venues, the Laboratory will leverage strengths in architecture development, sensors, and situational awareness systems to enhance capabilities.

Tactical Systems

Principal Accomplishments

Lincoln Laboratory is conducting an assessment of the capabilities of infrared sensors and seekers. A major focus has been the development of instrumentation to captive carry a long-wave infrared search-and-track and imaging infrared seeker.

The Laboratory demonstrated an advanced airborne signals intelligence (SIGINT) capability in an operational demonstration outside the continental United States. The Laboratory is transitioning the technology to industry for use in a next generation of advanced SIGINT capabilities.

The Laboratory is continuing a significant effort to develop and transition two novel airborne sensor systems for use in a quick-reaction, multiple-intelligences (multi-INT) ISR capability. Both systems will be fielded this year.

The Laboratory is prototyping a new type of ground-penetrating radar technology and will develop a field-worthy prototype for operational demonstration.

A robot-mounted sensor technology was transitioned into production and successful operational use by route-clearance engineer teams.

Future Outlook

Lincoln Laboratory will continue to provide assessments and testing in support of US Air Force acquisition decisions in air vehicle survivability, electronic attack, and other areas. Test assets, such as the Airborne Countermeasures Test System, and development of modern threat radar emulators will evolve to support these efforts.

The Laboratory will play a larger role supporting the US Air Force in the area of information dominance. Initial activities will include assessment of sensor options and development of a road map for counterterrorism efforts.

The Laboratory's efforts in the counterterrorism area will increase, with greater emphasis on development and demonstration of ISR architectures. Specific trends include multi-INT integration and the development of more advanced sensors for small unmanned aerial vehicle platforms. The Laboratory continues to rapidly develop advanced sensors.

Air Traffic Control

Principal Accomplishments

The Laboratory-developed Corridor Integrated Weather System (CIWS) was reengineered to provide continental United States (CONUS) coverage and a robust configuration suitable for handoff to FAA for long-term operation.

A prototype NextGen weather system providing eight-hour CONUS-wide storm forecasts was developed by blending CIWS technology with a high-resolution, rapid-update numerical weather prediction model. The system was evaluated in operational air traffic control (ATC) facilities in 2010.

A Tower Flight Data Manager for future air traffic control towers is under development. The system includes integrated surveillance and electronic flight-data displays as well as decision support tools to aid controllers in managing airport configuration, runway assignment, aircraft sequencing, taxi routing, and departure route assurance. A prototype was developed and tested in simulations; field evaluations are ongoing at the Dallas/Fort Worth International Airport.

Laboratory researchers have been assessing the performance of the Traffic Alert and Collision Avoidance System (TCAS) in airspace with reduced vertical separation, as well as supporting FAA in the definition of a next-generation TCAS.

Future Outlook

The Laboratory will continue developing NextGen ATC tower surveillance, automation, and decision support capabilities to improve safety and efficiency at conventional, on-airport towers and to potentially permit migration of ATC services to remote locations at appropriate airports.

Applications are planned to leverage the Automatic Dependent Surveillance–Broadcast (ADS-B) system to improve safety, efficiency, and capacity in congested airspace. Lincoln Laboratory will be instrumental in developing safety cases for these applications and in demonstrating robustness during "off-nominal" conditions.

There will be an emphasis on development and testing of next-generation aircraft-separation assurance on the airport surface and during flight. This effort will include evolution of collision-avoidance systems such as TCAS and Runway Status Lights, as well as simulation, analysis, and testing of future concepts.

Engineering

Principal Accomplishments

Lincoln Laboratory fabricated and shipped four Missile Alternative Range Target Instrument (MARTI) payloads to San Nicolas Island, CA, for launch (Figure 9). MARTI provides in situ radiometric diagnostics for airborne laser testing. In preparation for delivery to the field, the payloads were taken to Wallops Island Flight Facility in Virginia for integration and test with the booster. Two payloads were launched, and the MARTI data were successfully collected on missions that were important milestones for the airborne laser program.

Figure 9. The launch team is shown with a Missile Alternative Range Target Instrument integrated on a rocket for airborne laser test bed characterization.

In the robotics area, work was begun to bridge the gap between academic robotics and practical applications for DOD programs. An example application is autonomous mapping of GPS-denied interior spaces, which is necessary to localize data (e.g., video) acquired by exploration robots doing damage assessment or subterranean exploration. The Laboratory has demonstrated real-time, autonomous mapping with a single robot. A map is optimized and extended in real time as the robot autonomously explores a space.

The Laboratory researched state-of-the-art fabrication equipment that will improve quality, reduce cycle time and cost, and enable cutting-edge design solutions. Implementation of a three-year strategy has begun to bring these new capabilities into the Laboratory. These investments enable significant new capabilities in printed circuit board assembly, precision machining, rapid prototyping, and inspection.

Future Outlook

Work will continue on diverse hardware projects: integrating the Haystack Ultrawideband Satellite Imaging Radar antenna, finalizing the Lunar Laser Communications Demonstration design and initiating its fabrication, and developing rapid prototype systems. New efforts include spacecraft and aircraft payloads for laser communications and passive optical sensing and systems for detecting improvised explosive devices.

Emphasis continues on improving engineering facilities, including advanced tools for mechanical fabrication and electronic assembly. The mechanical inspection facility will be completely refurbished. Because the large number of programs requiring clean-room assembly areas has been straining the infrastructure, new clean rooms are under construction, and plans will be developed for specifying the capabilities needed in future new construction.

Lincoln Laboratory will continue expanding its robotics programs, making use of the techniques and experience gained from the autonomous mapping project.

Technology Transfer

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 (STTR) projects, which are joint research partnerships with small businesses; and Cooperative Research and Development Agreements (CRDAs), which are privately funded by businesses to transfer the Laboratory's technology. Technology transfer activities over the past year include the following:

- The Laboratory began the transfer of fully depleted silicon-on-insulator (FDSOI) complementary metal oxide semiconductor (CMOS) process technology to the Defense Microelectronics Activity (DMEA), which is responsible for ensuring the availability of critical electronics components to the military. The FDSOI CMOS technology will extend the range of semiconductor devices available through DMEA to include low-power devices, high-quality RF devices, and 3D integrated circuits.
- As a result of a DOD-sponsored transfer of the Laboratory's silicon and indium phosphide Geiger-mode avalanche photodiode technologies to US industry, Boeing is now marketing a compact, 3D laser radar camera.
- Improved orthogonal-transfer charge-coupled devices were delivered to the University of Hawaii for use in the focal plane of the second Panoramic Survey Telescope and Rapid Response System (Pan-STARRS) optical system. Pan-

STARRS is being developed to rapidly perform whole-sky surveys to detect and catalog asteroids and comets that may be threats to Earth.

- The Laboratory is continuing two CRDAs and is working on five STTR programs, including new projects in the areas of wideband receivers and optics for free-electron lasers. The Laboratory also has nine collaboration agreements with academic and nonprofit institutions.
- Between June 1, 2010, and June 28, 2011, MIT was awarded 14 US patents for technologies developed by Lincoln Laboratory researchers.

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 Workshop
- Space Control Conference
- Air Vehicle Survivability Workshop
- Ballistic Missile Defense Workshop
- Lincoln Laboratory Communications Conference
- Cyber and Netcentric Workshop

In addition, the Laboratory presents technical courses for military officers, DOD civilians, and defense subcontractors:

- Defense Technology Seminar
- Introduction to Radar Systems
- Introduction to Intelligence, Surveillance, and Reconnaissance
- Networking and Communications
- 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 diverse venues in which Lincoln Laboratory researchers publish. The technical staff publishes 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. In calendar year 2010, 134 papers were published in proceedings from such conferences, and nearly 70 articles were published in technical journals.

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

Collaboration with the MIT Campus

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, 19 MIT alumni became staff members at Lincoln Laboratory.

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

Integrated Photonics Initiative

A unique partnership between Lincoln Laboratory and the MIT campus is the Integrated Photonics Initiative (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. The IPI co-organized a workshop on coherent optics at the 2010 annual meeting of the MIT Center for Integrated Photonic Systems. Participants from academia, industry, and government discussed coherent optics challenges and needs within the telecommunications industry and the DOD.

Beaverworks

Last year, through a partnership with the MIT Department of Aeronautics and Astronautics, Lincoln Laboratory enlisted undergraduate and graduate students in a real-world project to build an unmanned aircraft. The project was envisioned as the first in an ongoing collaboration dubbed "Beaverworks" in reference to the MIT mascot and the term "skunk works," an industry label denoting an assignment-specific group working on a specialized project.

This year, two Beaverworks projects are under way. Students from professor David Miller's classes are working with Dr. William Blackwell, a senior staff member in the Sensor Technology and System Applications Group, on a project called MicroMAS (Microsized Microwave Atmospheric Satellite). The goal of MicroMAS is to leverage campus spacecraft technology expertise, Lincoln Laboratory sensor expertise, and commercial off-the-shelf parts to reduce the cost of earth science missions by more than an order of magnitude relative to the current state of the art. In the other project, the Laboratory's Tactical Defense Systems Group is collaborating with professor John Hansman and students to develop a novel, low-cost, very small unmanned aerial vehicle (micro-UAV), which is deployed at high altitude from a flare launcher and can remain on station for more than 30 minutes.

Research Collaborations

Collaborations with MIT foster mutually beneficial technical exchanges. Research projects are directly related to the Laboratory's mission areas or are investigations into emerging technologies of interest to the Laboratory. During 2010 and 2011, more than 40 research collaborations were ongoing with MIT departments and labs. These projects included development of the Line-of-Sight Tool (LOST) for aerial mission planning (with the Department of Aeronautics and Astronautics), research into computational imaging (with the Department of Electrical Engineering and Computer Science and the Media Laboratory), research on compact low-power charge-coupled devices for nanosatellites (with the Department of Earth, Atmospheric and Planetary Sciences and the Kavli Institute), research on exploiting clouds for laser communications (with the Research Laboratory of Electronics), and an investigation of a natural-language query for extracting knowledge from sensor data (with the Computer Science and Artificial Intelligence Laboratory).

Infrastructure Improvements

Of primary importance is the availability of adequate physical facilities for the evolving needs of the Laboratory's advanced technology programs. In addition, steady growth in programmatic areas has brought a gradual increase in personnel such that the Laboratory is now "stretched to the seams." A long-range plan for adding modern laboratory spaces and alleviating office overcrowding is being developed.
A primary goal is to replace an existing 1950s-era building with a modern one that will include fabrication labs and high-bay space appropriate for rapid prototyping as well as other lab spaces and clean rooms. A series of enabling moves will be needed as the first steps toward emptying the building that will be taken down and toward relieving overcrowding. In late 2011, the Air and Missile Defense Technology Division is expected to move into leased space currently being refitted in an industrial park about a mile and a quarter from the main Laboratory complex. This move will begin the process of relocating staff and spaces. The Laboratory is exploring options to relocate staff from multiple departments into leased refurbished office space on Hanscom Air Force Base property.

Services

The Laboratory continues to augment support services. Some of the improvements made are highlighted below:

- In 2011, after a lengthy development and test period, the Information Services Department launched a new internal network that provides tools to promote collaboration among technical divisions/groups and among user and special interest groups. In addition, divisions, departments, and offices have the ability to self-publish to their Intranet pages, thereby keeping information timely and freeing up IT resources for other projects.

- The Security Services Department, which received its fifth "superior" security rating from the US Air Force's 66th Air Base Group Information Protection Office, strengthened its security education and awareness program with the addition of new seminars, some presented by experts from agencies such as the Defense Security Services and the Federal Bureau of Investigation (FBI); the introduction of a computer-based IT security training module that must be completed by all employees; and a major expansion of the resources on its internal website.
- The Business Process Improvement program, coordinated by the Information Services Department and the Financial Services Department, is implementing new tools that will aid in analyzing, forecasting, and managing the Laboratory's funding. This program is a multiphase initiative designed to provide an integrated system that ensures data integrity and transparency.
- Two years ago, the Contracting Services Department introduced eCat, an electronic shopping portal that provides Laboratory purchasers of many commodities (hardware, electronics components, chemicals, etc.) with centralized access to multiple electronic catalogs and more efficient processing of purchase orders. This initiative continues to grow, with more than 30 vendors now available through eCat.

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. In 2010, the Communications and Community Outreach Office added a grant-funded STEM coordinator to its staff to manage the expanding portfolio of educational activities, examples of which follow.

- In March 2011, the Laboratory, in partnership with the Boston chapter of the Society of Women Engineers, held an all-day, hands-on engineering immersion program—"Wow! That's Engineering!"—for girls of middle school age. The success of this program led to it being repeated in July 2011.
- The Laboratory has expanded its program with the John D. O'Bryant School of Mathematics and Science in Roxbury, MA, to include assistance with its robotics team and an after-school program.
- LLCO launched the "Ask the Scientist" website this year. Each week, a Laboratory scientist answers a question sent in by a student. The featured answer is accompanied by links to further information and activities.
- The Laboratory is planning to host an experiential learning summer workshop for incoming high school seniors. The workshop's primary project is the construction and demonstration of a small radar system. Currently, proposals for a residential and a nonresidential program are being developed.

- Lincoln Laboratory's robotics initiative, Robotics Outreach at Lincoln Laboratory (ROLL), has expanded the number of teams it mentors in the FIRST (For Inspiration and Recognition of Science and Technology) competitions to 15, from seven in 2009. Two teams won top awards at the FIRST World Championship held in St. Louis April 28–30, 2011. In addition, a robotics team participated in the SeaPerch Derby held in New Bedford, MA, at which remotely operated underwater vehicles competed in performing tasks.
- "Science on Saturday," the Lab's first STEM program, is still drawing 700 K–12 students, parents, and teachers to each of the five annual onsite science demonstrations given by technical staff members during the academic year. The 2010–2011 topics were robotics, how computers work, how computers communicate with each other, acoustics, and the physics of amusement park rides (Figure 10).
- 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 Laboratory's technical staff.
- The Laboratory's other established educational outreach programs—classroom presentations at local schools by technical staff members, the LIFT2 internship program for teachers, and the Ceres Connection, which names asteroids in honor of science fair winners—are all continuing.

Figure 10. During a Science on Saturday event, a volunteer helps Laboratory engineers demonstrate the physics behind a roller coaster.

Community Service

The Laboratory's community service program has grown. This year's new initiatives included participation in the TeamWalk for CancerCare and the Great Strides for Cystic Fibrosis walk, collection of toiletries and blankets for the needy, and volunteer work at a food pantry. The ongoing campaign to collect and mail food, toiletries, and books to US soldiers overseas resulted in 200 "care" packages being sent to US troops in Iraq and Afghanistan. The Memory Walk for the Alzheimer's Association raised more than $13,000 to provide services to patients in Massachusetts and New Hampshire. LLCO again facilitated participation in the Bike and Hike the Berkshires event that raises funds for the Multiple Sclerosis Society; $15,680 was raised by the bike and hike team. The annual holiday clothing, food, and gift drives brought in 435 warm coats, food for 170 families, and 300 gift items.

Summary

Demand for Lincoln Laboratory's research remains strong, and the sources of sponsorship are diverse. Current programs extend from fundamental investigations to developmental engineering and operational testing of systems. The Laboratory's portfolio is well balanced with system development in core missions, innovative research projects, and large-scale programs.

Emerging national concerns are leading to opportunities for research and development in areas such as tactical systems, cyber security, quantum information sciences, and decision support technologies. Work in the Advanced Technology Division is increasingly multidisciplinary, and the broad scope of the division's work on enabling technologies includes high-performance detectors and focal planes, three-dimensional integrated circuits, microelectromechanical devices, and unique lasers. Rapid prototyping efforts continue to grow.

Ongoing improvements to support engineering, administration, and infrastructure sustain the Laboratory's ability to achieve technical excellence. Charitable giving activities are providing needed resources to local communities and organizations, and the educational outreach program is expanding, particularly in its reach to students in underserved communities. In conclusion, Lincoln Laboratory is well positioned to take on the challenges of its mission of service to the nation.

Eric D. Evans
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