Lincoln Laboratory

Lincoln Laboratory, a federally funded research and development center (FFRDC) operated by the Massachusetts Institute of Technology, is also a designated Department of Defense (DOD) Research and Development Laboratory. Lincoln Laboratory, operating under a prime contract with the Department of the Air Force, conducts research and development pertinent to national defense on behalf of the military services, the Office of the Secretary of Defense, the intelligence community, and other government agencies.

The mission of Lincoln Laboratory is to advance system and technology development in support of national security. Three core areas constitute the research and development carried out at the Laboratory: sensors, information extraction (signal processing and embedded computing), and communications, all supported by a broad research base in advanced electronics. Lincoln Laboratory projects focus on the development and prototyping of new technologies and capabilities for which the government cannot rely on in-house or private-sector resources.

For the federal fiscal year 2007, Lincoln Laboratory will receive approximately $624.8 million that will support the efforts of approximately 1,500 professional technical staff and 1,000 support personnel; outside procurement will exceed $265 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), and the National Oceanographic and Atmospheric Administration. In addition, Lincoln Laboratory also carries out noncompetitive research with industry under approved cooperative research and development agreements and other collaborative activities with academic institutions.

On April 1, 2005, the DOD awarded a five-year reimbursement contract with a five-year option to MIT for the operation and management of Lincoln Laboratory as an FFRDC. 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 56 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 high-caliber staff, streamlined organizational structure, high-quality infrastructure, well-defined strategic focus, and strong alignment with the MIT campus.

Organization

The Laboratory's performance depends on its technical staff. The flat organizational structure, consisting of three levels—the Director's Office, divisions and departments, and groups—encourages the exchange of ideas between staff and line management. The increasing demand on the Laboratory to conduct research on and develop more complex, integrated systems has raised the level of collaboration among staff, facilities, and services. As providers of standardized support, service departments allow research teams staffed from across the divisions to quickly draw on key services and to focus on the technical challenges.

Key Changes to the Laboratory Organization

Two new offices reporting to the Director's Office were established.

- The Chief Technology Office was created to strengthen the direction and focus of the Laboratory's long-term technology strategy and, to this end, will work closely with the Defense Advanced Research Projects Agency (DARPA), the Office of Naval Research, the Air Force Research Laboratory, and other military service program offices to develop and coordinate technology programs.
- The Mission Assurance Office was established to develop a Lincoln Laboratory implementation of the aerospace AS9100 mission assurance standard. This standard is applied to large hardware and software efforts to enhance program success, satisfy sponsor requirements, maintain configuration control, and identify and mitigate risks.

A new administrative service department has been established. Effective August 1, 2007, the Contracting Services Department assumed responsibility for the functions previously handled by the Purchasing Group and for the following:

- The Laboratory's prime contract with the DOD
- Cooperative research and development agreements, grants, and off-contract actions
- Nondisclosure agreements and intellectual property
- International traffic in arms regulations
- Contract support and administration for Level 1 program.

Key Changes to the Laboratory's Strategic Direction

Lincoln Laboratory has responded to increased DOD focus on homeland security and counterterrorism by establishing a homeland protection mission center. This mission area will be within the division formerly known as Tactical Systems Technology. The division has been renamed Homeland Protection and Tactical Systems. In addition, the Biodefense Group, which previously was a part of the Aerospace Division, has joined the Homeland Protection and Tactical Systems Division.

Also, to reflect the growing emphasis on integrated sensing and decision support, the division formerly called Sensor Systems has been renamed Intelligence, Surveillance, and Reconnaissance (ISR) Systems and Technology, and the Directed Energy Group from that division has merged with a group within the Solid State Division to become the Laser Technology and Applications Group.

Key Changes to the Laboratory's Senior Management

Dr. Marc D. Bernstein was appointed head of the Air and Missile Defense Technology Division.

Dr. Darryl P. Greenwood joined the Homeland Protection and Tactical Systems Division as associate head, and Dr. Israel Soibelman was appointed assistant head of that division.

Dr. J. Scott Stadler was appointed head of the Communications and Information Technology Division, and Dr. Marc A. Zissman and Mr. Stephan B. Rejto were appointed assistant heads.

Dr. Charles A. Primmerman was appointed associate head of the Solid State Division.

Dr. Hsiao-hua K. Burke was appointed associate head of the Aerospace Division.

Dr. James Ward was appointed assistant head of the Intelligence, Surveillance, and Reconnaissance Systems and Technology Division.

Mr. Paul F. Conroy was appointed head of the new Contracting Services Department.

Mr. James F. Ingraham was appointed head of the Financial Services Department.

Mr. Ronald L. Hersey was appointed acting head of the Information Services Department.

Dr. Kenneth Roth, Dr. Kenneth Senne, Mr. Peter Blankenship, and Mr. Frank Schimmoller stepped down from the Steering Committee.

Please refer to figure 1 for an overview of the current Laboratory organizational structure.

Staff

A key factor in maintaining excellence at Lincoln Laboratory is the quality of its staff. The Laboratory obtains 65–75 percent of its new staff directly from the nation's leading technical universities. The Laboratory conducted on-campus interviews at over 50 universities this past year. The makeup of the Laboratory staff by degree and academic discipline is shown in figure 2.

This year a number of Lincoln Laboratory staff members have been recognized for their achievements in their fields and for their commitment to professional activities. Dr. David L. Briggs, director emeritus, was awarded a 2007 Missile Defense Agency (MDA) Pioneer Award for significant and sustained technical contributions to missile defense systems. Dr. Joseph C. Chow, former group leader in the Aerospace Division, was awarded a 2007 MDA Pioneer Award for his contributions to the Midcourse Space Experiment Program of the 1990s. This year Dr. Pratap N. Misra was elected as a fellow of the Institute of Electrical and Electronics Engineers (IEEE) for contributions to global

Figure 1. MIT Lincoln Laboratory organizational structure.

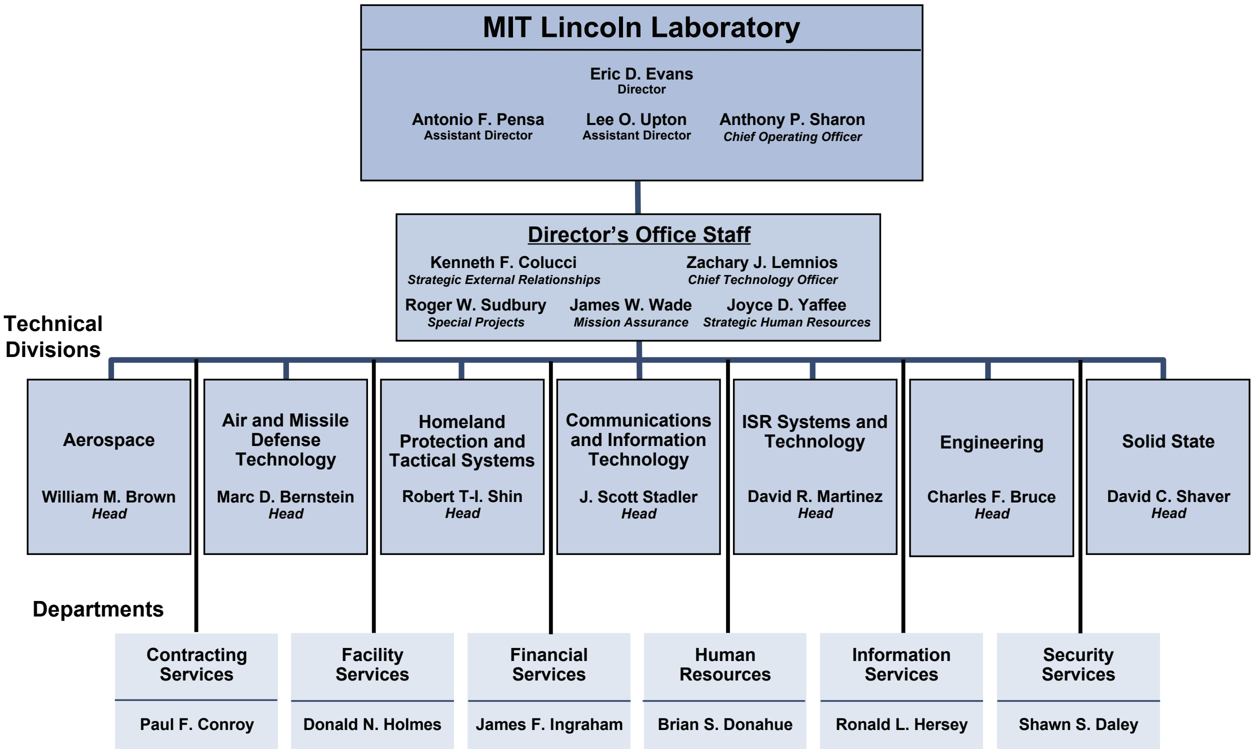
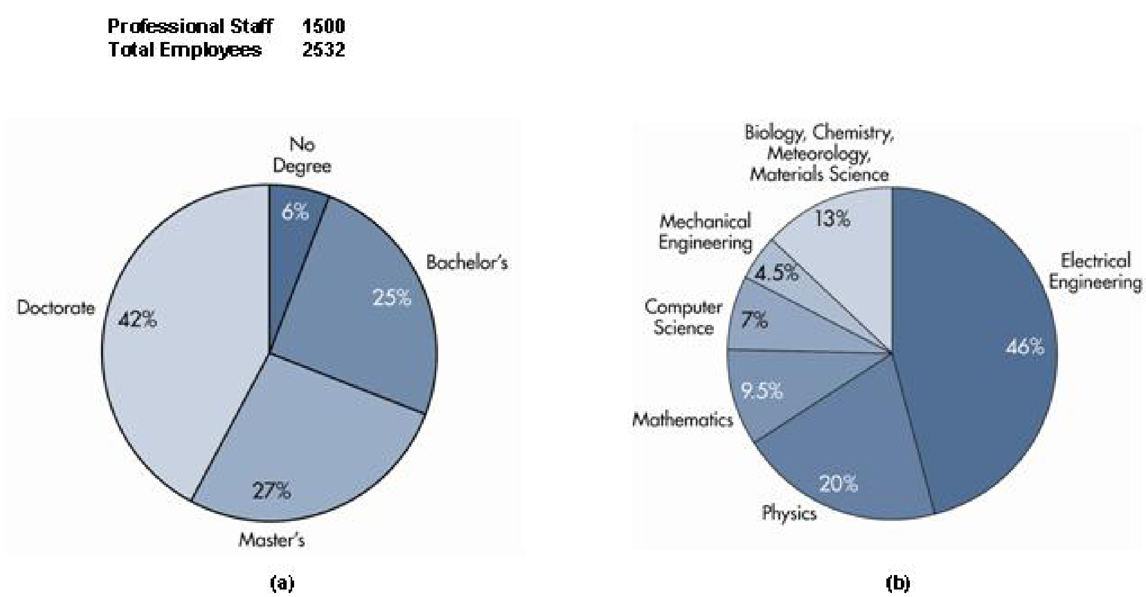


Figure 2. Composition of professional staff at MIT Lincoln Laboratory by (a) degrees and (b) academic disciplines.



satellite navigation systems. Dr. Robert M. O'Donnell was appointed vice president for education for the IEEE Aerospace and Electronic Systems Society.

This year, under the sponsored research program, the Laboratory hosted 53 graduate and 34 undergraduate students. Specific to MIT, the Laboratory recently hosted 10 Course 6-A Mechanical Engineering students, one Undergraduate Research Opportunities Program student, and one Undergraduate Practice Opportunities Program student. In an ongoing collaboration with the Worcester Polytechnic Institute, 16 seniors completed their major qualifying projects at Lincoln Laboratory. The collaboration with Tufts University Department of Electrical and Computer Engineering has allowed four students to carry out research projects at Lincoln Laboratory. In addition, 32 students from Northeastern University's cooperative study program were employed at the Laboratory.

The Laboratory's professional development initiatives include a program of onsite courses. Recent onsite courses include Fundamentals of Probability and Statistics, Information Fusion for Decision Support, and the Technology Awareness Series. The Laboratory also offers a variety of seminars. Division and staff seminars on current research are offered every week, and special seminars are often brought to the Laboratory. For highly qualified candidates, the Laboratory offers the opportunity to apply to the Lincoln Scholars program, which supports the pursuit of advanced degrees. The Lincoln Scholars program currently has 11 doctoral and 22 master's candidates, primarily in electrical engineering and computer science. This year seven Lincoln Laboratory staff members completed their master's degrees and four completed doctorates.

Technical Program Highlights

Research at the Laboratory focuses on national security tasks involving tactical and ISR systems technology, air and missile defense, space situational awareness, biological-chemical defense, communications and information technology, and advanced electronics technology. In addition, for other government agencies the Laboratory undertakes related nondefense work, including air traffic control. A principal activity is the development of components and systems for experiments, engineering measurements, and tests under field operating conditions.

The Laboratory is working on over 390 specific engineering development projects. Notable highlights for each mission area, as well as future directions, are listed below.

Space Control

Principal Accomplishments

- The Space Systems Analysis Group was established to focus on system-level studies of the US national space enterprise.
- The Extended Space Sensor Architecture (ESSA), a net-centric test bed for space situational awareness, had its first deliveries into the Joint Space Operations

Center (JSPOC). This capability provides real-time radar images from the Haystack Auxiliary sensor to JSPOC operators.

- A multistatic radar test bed, consisting of Haystack and Haystack Auxiliary illumination radars (components of the Lincoln Space Surveillance Complex), three fixed received sites, and one transportable receive site, began operations. The test bed was used to demonstrate wideband bistatic tracking and interferometric 3-D inverse synthetic aperture radar imaging of satellites in low Earth orbits.
- Initial optical processing to shape each of the three large mirrors on the Space Surveillance Telescope (SST) has been completed. The telescope gimbal has been assembled. SST operations are scheduled to begin in late 2009. The SST will possess an advanced ground-based optical system to enable detection and tracking of objects in space while providing rapid, wide-area search capability.
- The Haystack Ultrawideband Satellite Imaging Radar (HUSIR) low-power driver tube transmitter and signal processor were integrated with a small (2.4 m) antenna and successfully used to collect data from large, low Earth-orbiting satellites. This early test confirms operational readiness for integration with a 37 meter-diameter dish antenna. The HUSIR system will add significant new imaging capability to our nation's space situational awareness network.
- Millstone Hill radars (figure 3) and the Space-Based Visible sensor have provided space situational awareness data to support more than 50 new launches in the past year.

Figure 3. The Lincoln Space Surveillance Complex in Westford, Massachusetts, constitutes the foundation of the Laboratory's ground-based radar space surveillance programs.

- Focal plane detectors and readout electronics were delivered for the Extreme Ultraviolet Experiment sensor on NASA's Solar Dynamics Observatory.
- A novel 256 × 256 long-wave infrared detector array capable of supporting 30,000 frames per second with pixel-level digitization and image processing was fabricated. This technology will enable the next generation of nighttime wide-area surveillance.
- Fabrication and initial testing were completed for an 880-megapixel visible wavelength imager that enables wide-area persistent surveillance at up to 10 frames per second.

Future Outlook

The Laboratory's focus in the upcoming year includes:

- Continued work in advanced radar development, radar surveillance, space-object identification, electro-optical deep-space surveillance, collaborative sensing, and sensor fusion and processing.
- Development of the HUSIR and SST sensor systems, which will bring new capability to
the Space Control mission area. Information from these new sensors will be integrated with the ESSA test bed.
- Pursuit of new initiatives in the Space Control area, including the next generation of sensor systems and downstream processing/information extraction systems, such as
  - a small-aperture, space-based, space surveillance system to provide wide-area search of the geosynchronous belt
  - a passive, ground-based, wide-angle "fence" search system for detecting low Earth-orbiting satellites, using unique curved charge-coupled device focal planes to achieve the wide coverage
  - net-centric machine-aided decision-support algorithms to allow the operators in the Joint Space Operations Center to react to short-timeline taskings.

Air and Missile Defense Technology

Principal Accomplishments

Missile Defense

- A sensor sidecar for the Aegis AN/SPY-1 radar was developed to test discrimination algorithms and architectures for the Aegis Block 08 Ballistic Missile Defense capability. The sidecar was integrated with the AN/SPY-1 radar at a contractor facility and was installed on an Aegis BMD operational cruiser for use in an Aegis BMD intercept test in June 2007.
- The Laboratory completed a successful critical measurements and countermeasures (CMCM-2) flight test at the Pacific Missile Range Facility in Hawaii. A long-range test target with advanced countermeasures was launched, and radar and optical data were collected to reduce risk for the development of advanced counter-countermeasure capabilities.
- The Laboratory demonstrated discrimination algorithms and decision logic for the MDA's Forward-Based Radar (FBR) program. This demonstration was executed during the CMCM-2 test on a sidecar within the FBR test bed. The FBR algorithms and decision logic have been successfully transferred to a contractor for incorporation in the Forward-Based Radar.

- The Reagan Test Site (RTS) Distributed Operations (figure 4) project achieved significant milestones this year, including real-time demonstrations involving the control of RTS radars from Lexington. This new capability will allow operators to view and execute missions from geographically dispersed operational sites.

Figure 4. The Reagan Test Site Distributed Operations capability will allow operators to view and execute missions from geographically dispersed operational sites.

Air Defense

- The Laboratory collected and analyzed data from the initial flight tests of the Navy's E-2D Advanced Hawkeye C-130 test bed to verify the performance of the new radar system for the E-2D. A separate test campaign was conducted at the Point Mugu Test Range to examine the performance of advanced waveforms for the E-2D.
- The Laboratory completed development of a signal processing sidecar for a ground-based surveillance radar. The sidecar will be used for testing advanced electronic protection techniques against electronic attack systems. It includes modern displays, auxiliary antennas and receiver channels, and high-speed instrumentation.
- A new pod was developed for the Airborne Seeker Test Bed, enabling captive carry of a variety of man-portable air defense missile seekers. The missile seekers were also tested extensively in the Laboratory's passive optical system test facility, and the measurements were used to validate detailed seeker models for air vehicle survivability.
- The Laboratory is helping the Air Force develop goals and new technology to correct gaps in capabilities against future threats, particularly in the areas of electronic attack and electronic protection. The Laboratory is developing a new airborne test bed based on a converted aircraft to test the electronic protection performance of advanced Air Force sensors.

Future Outlook

- The Laboratory will have a large role in characterizing the capabilities and limitations of the recent initial operational deployment of the Ballistic Missile Defense System (BMDS) and in helping to develop, refine, and verify tactics, techniques, and procedures to optimize performance. The Laboratory will also be actively engaged in the analysis, development, testing, and implementation of capabilities for the BMDS beyond the initial deployment. Areas of particular focus will be system-wide tracking and discrimination, system-level testing, and advanced counter-countermeasures techniques.
- The Laboratory will be working with MDA, US Northern Command/North American Aerospace Defense Command, and US Strategic Command to define architectures for the defense of the US homeland against asymmetric attacks by

cruise missiles or short-range ballistic missiles launched from ships off the US coast. An initial prototyping effort is being examined for the National Capital Region as an extension of the Enhanced Regional Situation Awareness (ERSA) system currently in place to provide a defensive capability against these threats.

Communications and Information Technology

Principal Accomplishments

- Lincoln Laboratory delivered a test and evaluation capability to validate design standards for critical transformational communications technologies, including protected RF waveforms, IP networking, and lasercom. In collaboration with industry, the test infrastructure was used to verify standards, validate specific implementations, and establish technology readiness.
- The Laboratory delivered a Ka-band “over-the-air” test capability to Camp Parks, California, for use in early on-orbit checkout of the Wideband Global System satellite communications payload.
- The Laboratory conducted flight-test campaigns to assess the effectiveness of airborne intelligence, surveillance, and reconnaissance; airborne networking; and network middleware concepts.
- The Laboratory deployed the Lincoln Adaptable Real-time Information Assurance Test bed (LARIAT) to several government facilities. LARIAT provides a high-fidelity emulation of large-scale networks with up to thousands of hosts and tens of thousands of users to evaluate the effectiveness of information operations tools and techniques.
- Lincoln Laboratory-produced speaker- and language-recognition algorithms achieved world-leading performance in international evaluations conducted by the National Institute of Standards and Technology.
- The Laboratory has demonstrated a system that assesses the security of enterprise networks and automatically recommends changes to eliminate vulnerabilities.
- Lincoln Laboratory continued a series of operator-in-the-loop evaluations of airborne network nodes and architectures. The Laboratory teamed with industry to compare the effect of different network architectures on mission outcome using pilots in real-time, full-motion flight simulators.
- Lincoln Laboratory continues to work closely with industry to realize low-profile, low-cost, multiband antennas for use on wide-body and fighter aircraft. These apertures are designed to support the data rates necessary for network operations while having minimal impact on platform performance.
- A demonstration was completed of an ultraefficient laser communications link capable of sending 1 megabit per second over 1.6 km with 1 microwatt of transmit power. The receiver can decode 2 bits for each received photon, and the transmitter can control precision pointing of the laser with no moving parts.

- A programmable digital core consisting of field programmable gate arrays, digital signal processors, and a general-purpose computer was completed and delivered. The digital core is capable of processing a wide spectrum of communications waveforms, ranging from line-of-sight radios to protected satellite communications (figure 5).

Figure 5. Lincoln Laboratory has pioneered apertures and algorithms that provide communications on the move.

Future Outlook

The Laboratory's focus in the upcoming year includes:

- Delivery of an interim command-and-control capability and a calibration facility to support the initial operation of the Advanced EHF Satellite
- Addition of functionality to the Transformational Communications technology test beds and their integration to verify end-to-end operation
- Service-oriented architecture techniques for sharing data and enabling dynamic work flows among diverse network-connected sensors, processors, and decision-support tools
- Algorithms for speech, language processing, and information operations techniques for use in Counterterror Social Network Analysis and Intent Recognition
- Field measurement campaigns as part of the US Army C4ISR experiments and Empire Challenge, using the Paul Revere airborne laboratory and the prototype comm-on-the-move vehicles
- Development of test bed and evaluation techniques for two-way English-Arabic and English-Mandarin speech-to-speech translation
- High-sensitivity optical receivers that enable small, high performance lasercom terminals for air, ground, and space applications.

Intelligence, Surveillance, and Reconnaissance Systems and Technology

Principal Accomplishments

- The Laboratory developed a new airborne radar concept for wide-area detection of moving targets concealed under foliage. This concept uses a multichannel sparse antenna and adaptive signal processing to combine synthetic aperture radar images from each transmit-and-receive channel to reject ground clutter returns. An experimental prototype was designed and successfully tested using the Laboratory's airborne test bed. (Figure 6 shows one of the sensors used to provide radar imagery and ground moving-target detection.)

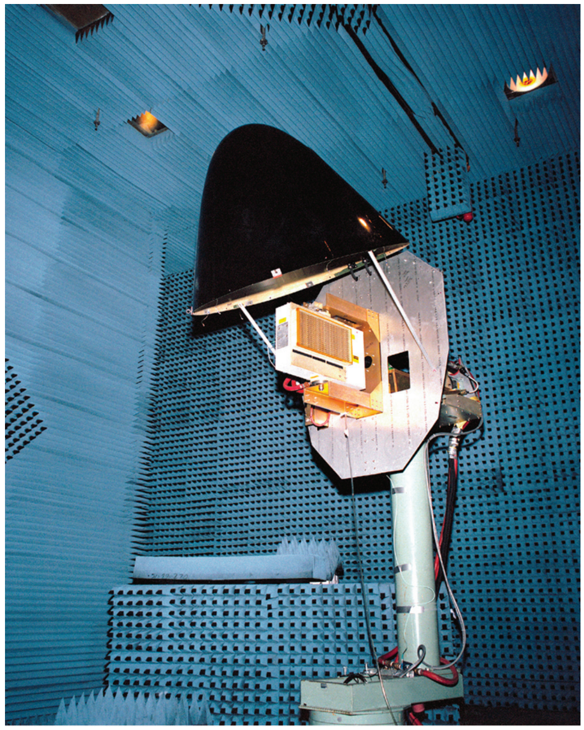


Figure 6. The active electronically scanned array that is part of the Lab's airborne sensor test bed is tested inside the Lab's antenna measurement facility. This sensor provides radar imagery and ground moving-target detection as part of the Lincoln Multimission ISR Test bed (LiMIT) currently residing on the Lab's airborne test bed.

- A novel nonlinear equalization algorithm was developed to reduce the nonlinear distortion produced by analog receivers and analog-to-digital converters in the front ends of many ISR systems. Computationally efficient approaches have been developed and shown to provide beyond 20 dB improvement in linear dynamic range. A nonlinear equalization very-large-scale integration chip that operates at 1,500 million samples per second is currently in fabrication.
- The Laboratory developed adaptive beamforming algorithms for submarine hydrophone arrays that provide significantly improved detection capability in noisy undersea acoustic environments. The Laboratory also developed a classification algorithm architecture that provides an operator with reliable alerts and the automation to manage large search spaces. The Laboratory utilized operational sensor data and transitioned improved capability to fielded sensor systems.
- Lincoln Laboratory continues to pioneer advanced software technology to provide highly efficient platform-independent signal and image processing functions for embedded systems. Development of the next-generation middleware, the Parallel Vector Tiled-Optimized Library (PVTOL), is well under way. PVTOL employs automated mapping and hierarchical memory

management to enhance the performance and programmability of the emerging generation of multicore microprocessors.

- A knowledge management system called Structured Knowledge Spaces was created to automatically link human-generated exploitation products back to their supporting sensor data. The system helps to improve an operator's ability to quickly find and correlate high-level information.
- The Lincoln Laboratory Grid (LLGrid) computing capability was established with the award of a large computing cluster from the DOD High Performance Computing Modernization Office. LLGrid now contains 1,500 processors and nearly a petabyte of disk storage. An integral component of the Laboratory's computing infrastructure, LLGrid is used to conduct large simulations, analyze large data sets, and prototype complex processing algorithms. LLGrid supports several programming languages.
- Laser radar technologies were combined with other sensing modalities such as electro-optics to improve the ability to discriminate targets and structural features in three dimensions.

Future Outlook

The Laboratory's focus in the upcoming year includes:

- Developing digital receiver technology for wideband, high dynamic range needs in passive systems
- Combining RF, video, and laser sensing for enhanced target tracking and identification
- Prototyping sensor payloads for small and medium-sized unmanned aerial vehicles (UAVs)
- Furthering development of very-high-resolution laser radar concepts for biometrics
- Developing open network-centric architectures for ISR systems.

Advanced Electronics Technology

Principal Accomplishments

- Progress continued in the development of high-performance photodetector arrays in which each pixel is sensitive to a single photon. Improved silicon Geiger-mode avalanche photodiodes were used to enable DARPA's Jigsaw ladar (laser radar) sensor to achieve high-range resolution in a recent measurement campaign. Expansion of applications from the original ladar to photon-counting passive imaging and high-rate optical communication achieved key in-laboratory validation.
- A 3-D integrated circuit technology, based on the Laboratory's silicon-on-insulator-based process, is being optimized for multicircuit-tier focal planes. In this architecture, the electronics for each pixel reside in tiers behind the high-fill-

factor photodetection tier, enabling key improvements.

- A unique orthogonal transfer array has been developed for synoptic space surveys in the Air Force's Panoramic Survey Telescope and Rapid Response System (PanSTARRS). Sixteen orthogonal transfer arrays have been assembled into a 4 × 4 abutted format, and field tests are being initiated at the telescope being built for PanSTARRS.

Figure 7. At Lincoln Laboratory's Microelectronics Laboratory, advanced microelectronic devices and semiconductor processing hardware are developed.

- Advances in RF performance and reliability of microelectromechanical (MEM) devices have resulted in fully packaged capacitive MEM switches with exceptional low loss and broadband performance across 3 to 110 GHz.
- The Laboratory worked with the Air Force Research Laboratory and a contractor to insert the GaSb-based infrared countermeasure technology into the Advanced Tactical Directed Energy System laser designed for aircraft self-protection.
- Recent advances also include the validation of several specialized charge-coupled device (CCD) imagers for satellite and terrestrial surveillance missions, the first demonstration of a 3-tier focal plane by a 3-D integrated circuit technology, and the preliminary test of large-format, curved focal plane CCD arrays within the Space Surveillance Telescope.

Future Outlook

The Laboratory's focus in the upcoming year includes:

- Imaging and RF technologies for DOD and civilian remote sensing applications
- Laser technologies supporting communication and targeting systems
- Cryoelectronics for longer-term impact in infrared sensing and high-speed computation
- Advanced packaging technologies for large tiled focal planes, miniaturized low-power RF systems, and optoelectronics
- New devices, processes, and design methodologies to enable lower-power, higher-performance digital electronics sensors to detect explosives and improvised explosive devices.

Homeland Protection

Principal Accomplishments

- Lincoln Laboratory demonstrated initial operation of a test bed designed to test potential chemical and biological sensors and protection methods.
- The Laboratory completed homeland security system architectures for biological defense in domestic settings, including indoor and outdoor attacks, a variety of bioagents, and various response strategies.
- The Laboratory completed the first phase of a border sensor architecture study for the southern border.
- New features were added to the ERSA system of radar and EO/IR sensors, track fusion logic, and evidence accrual tools. ERSA is deployed to the National Capital Region to provide enhanced air defense surveillance capabilities (figure 8).

Figure 8. The Enhanced Regional Situation Awareness Visual Warning System is used to provide air defense surveillance capabilities in the National Capital Region.

- The Lab completed a first-phase study to define architectures for the defense of the homeland against attacks by cruise and short-range missiles as well as unmanned aerial vehicles launched from ships off the US coast.
- Lincoln Laboratory developed an analysis methodology and software tools to evaluate ground sensor fusion concepts to provide an accurate air traffic picture to UAV operators.
- A suite of air-vehicle identification algorithms was rapidly developed to support homeland air defense applications. This effort leveraged a data-collection sensor built to support algorithm development and used to collect a rich set of commercial air-vehicle signatures. Algorithms specifically tailored to the domestic airspace environment were implemented, tested, and characterized with this data. The result was substantial intellectual property usable in future domestic air defense applications.
- In support of Department of Homeland Security (DHS) cyber-security efforts, the Laboratory developed a system, named DEADBOLT, which detects and locates buffer overflows in C and C++ programs.

Future Outlook

The Laboratory's focus in the upcoming year includes:

- Continued emphasis on biological and chemical agent sensing technologies
- Architecture studies, system development, and system evaluations for biological and chemical defense
- Expansion of sensor architecture studies for the prevention of terrorist entry across the southern and northern US borders
- Evaluation of fused ground sensor system concepts for the Fort Huachuca/Arizona border region
- Application of persistent surveillance technology to border surveillance and maritime domain awareness
- Oversight of a program to ensure the survivability and recovery of process control systems
- Development of additional capabilities for the ERSA system in support of air defense of the National Capital Region
- Application of airspace models to evaluate airborne collision-avoidance systems being developed for the DHS UAV operations

Aviation Research

Principal Accomplishments

- The FAA's production Integrated Terminal Weather System with the one-hour Terminal Convective Weather Forecast was deployed in New York, Dallas, Orlando, and Memphis. This marks the completion of Lincoln Laboratory's work on an FAA system from concept, research, and prototype to technology transfer, contractor development, production, and certified operations.
- Progress continued on the Corridor Integrated Weather System (CIWS) Demonstration, now in use in the northeast US at eight en route centers, six major terminal control areas, and the Air Traffic Control System Command Center (figure 9). A large software engineering effort to restructure the CIWS prototype will enable coverage of the continental US by 2008.

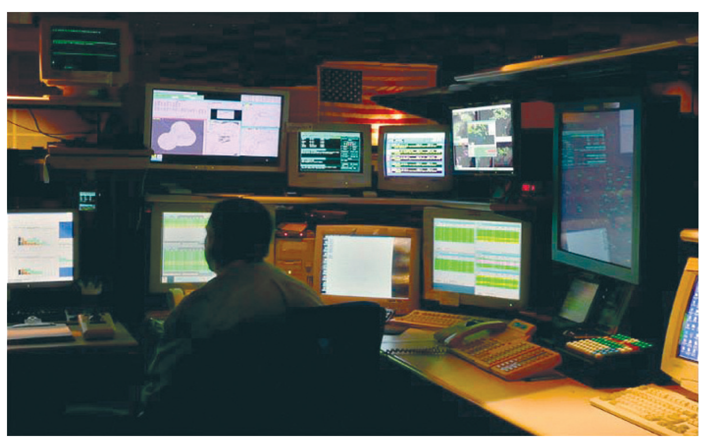


Figure 9. The air traffic control room for the New York/New Jersey airports is using the Laboratory-developed Integrated Terminal Weather System and the Corridor Integrated Weather System.

- The Route Availability Planning Tool (RAPT) represents the Laboratory's first work in the area of coupling weather forecast information into air traffic management decision-support tools. A live RAPT demonstration in New York and a benefits assessment of RAPT began in May. Application to other major US airports (Chicago's O'Hare and Atlanta's Hartsfield-Jackson) will begin.
- The Runway Status Lights operational evaluation at Dallas/Fort Worth International Airport is being extended to include more runways, as well as testing at Chicago's O'Hare airport. This system reduces the number and severity of runway incursions and helps prevent accidents.
- In support of the US Department of Defense, the Laboratory is developing technologies and certification procedures that will permit unmanned aerial vehicles efficient access to the National Airspace System. Key technologies include sense-and-avoid and collision-avoidance systems.
- The Laboratory commenced supporting the FAA in the development of required surveillance performance and fusion algorithms for Automatic Dependent Surveillance-Broadcast (ADS-B), the primary next-generation air traffic control (ATC) surveillance system.

Future Outlook

The Laboratory's focus in the upcoming year includes:

- Modern FAA communications architecture for weather information, including network-enabled weather for the National Airspace System
- New architecture for terminal and en route weather systems and sensors
- Broader coupling of weather and air traffic information, including prototype decision-support tools that incorporate weather and estimates of weather forecast uncertainty
- Improved assessment of performance and efficiency in the National Airspace System, including benefits of integrated weather systems and assessment of avoidable delay
- Demonstrations of enhanced surveillance capabilities with the Multifunction Phased Array Radar for air surveillance
- Development of integrated, net-centric surveillance architecture supporting ATC and homeland defense missions. Key sensor inputs include the ADS-B, operational ATC radar networks, and surge sensors.

Collaboration with MIT Campus

Lincoln Laboratory uses a Campus Interaction Committee to strengthen its ties and alignment with the MIT campus. The committee's principal focus is joint research and policy seminars and it is chaired by Professor Jeffrey Shapiro. Laboratory staff members were involved with 12 MIT graduate theses and with the Lincoln Laboratory/MIT Campus Seminar Series, which brings MIT speakers to the Laboratory and Laboratory technical staff to the campus. Emerging collaborative areas include photon integration, advanced signal processing, decision networks, and advanced energy technology.

A unique collaboration between Lincoln Laboratory and the MIT campus is the Integrated Photonics Initiative, a multiyear, Laboratory-funded effort that enhances the research experience for PhD candidates working on integrated photonics devices and subsystems for potential insertion into advanced communications systems. This year two doctoral students received waveguide etching and cleaving support from the Electro-Optical Materials and Devices Group, and one of these students had the optical switches he fabricated characterized and incorporated into a system demonstration by the Optical Communications Group.

Other collaborative efforts 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 improvement of current practices. The 2007 projects are listed below (* denotes an MIT researcher):

- Spin-Induced Fluid and Particle Manipulation for Bio-Terrorism Detection Systems (Researcher: J. D'Angelo)
- Organic-Based Solar Cells with Lithographically Defined Interfaces (Researchers: T. Bloomstein, Professor V. Bulovic*)
- Probing the Peptide-Inorganic Interface Using Optical Trapping in Novel Environments (Researchers: M. Lang, D. Appleyard*)
- Rapid Generation of Complex Neural Scaffolds (Researcher: M. F. Yanik*)
- Detecting Biomarkers of High Explosives in Hair and Other Matrices (Researchers: M. Sworin, D. Schauer*, S. Tannenbaum*)
- Transporting Fluid in Microfluidic Devices by Electrowetting Actuation (Researchers: S. Berry, J. Kedzierski)
- A Cell-Based Sensor for Genotoxic Agents (Researcher: Professor A. Rich*)
- Shadow Imaging of Geo Satellites (Researchers: J. Luu, L. Jiang, B. Willard)
- Dry Aerosol Generation (Researcher: J. Richardson)
- Algorithms for Unmanned Aircraft Collision Avoidance (Researchers: M. Kochenderfer, J. Kuchar, L. Kaelbling, T. Lozano-Perez*)

The Laboratory also supports activities conducted by the Industrial Liaison Program staff through presentations by Laboratory staff on cooperative research and development opportunities and technical licensing options. Working through the MIT Technical Licensing Office, the Laboratory has made 28 technology disclosures, applied for 25 US patents, and was awarded 19 US patents between July 1, 2006 and June 30, 2007.

One of our most valued ties to the campus is the exceptional alumni who join the Laboratory. This year, 17 MIT graduates became staff members at Lincoln Laboratory.

Community Outreach

The Lincoln Laboratory Community Outreach (LLCO) was established to promote service and education in partnership with the MIT Public Service Center.

The LLCO has focused on educational outreach. This year over 1,400 local K–12 students, along with their parents and teachers, attended science demonstrations given by Laboratory technical staff in the *Science on Saturday* program (figure 10). These demonstrations included ones on cryogenics and liquid nitrogen, properties and applications of sound waves, the "magic" of chemistry, and lasers and optics. Through the *Science Seminar Series*, technical staff have visited local K–12 schools, giving presentations on science and engineering to over 1,000 students.

Figure 10. A student becomes an assistant to Dr. Richard Williamson at his Science on Saturday demonstration, "Cryogenics and Liquid Nitrogen."

In community service initiatives this year, the LLCO divided proceeds from events such as a 5K fun run and a used book drive/sale between the United Way and the MIT Community Service Fund. The LLCO was also involved in other charitable initiatives:

- A clothing drive for local shelters
- A food drive for the Food for Free organization
- A national multiple sclerosis benefit bike/hike event for which the Laboratory received an award from the Multiple Sclerosis Society
- A drive that collected hundreds of goods for US soldiers overseas

Technical Education

The dissemination of information to the government, academia, and industry is one of the principal activities of Lincoln Laboratory's technical mission. Maximum dissemination of technical information is achieved through annual technical workshops and seminars hosted at Lincoln Laboratory. These workshops and seminars bring together members of technical and defense communities to share technology advancements and concepts. These events foster a continuing dialogue that strengthens technology development and provides direction for future research. Listed below are some of these workshops and seminars:

- High Performance Embedded Computing Workshop
- Surface Surveillance Technology Workshop
- Bio-Chem Defense Systems Workshop
- Advanced Electronics Technology Technical Seminar

- Space Control Conference
- Air Vehicle Survivability Workshop
- Ballistic Missile Defense Technical Seminar
- Adaptive Sensor Array Processing Workshop
- Communications and Networking Workshop

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

- Defense Technology Seminar
- Ballistic Missile Defense Technology Course
- Introduction to Radar Systems Course
- Homeland Defense and Counterterrorism Course (offered collaboratively at the Naval War College in Newport, Rhode Island)

Lincoln Laboratory staff publish articles in peer-reviewed journals, contribute chapters to books, and present at national technical conferences. During the past 18 months, Lincoln Laboratory staff published 91 technical articles in professional journals and delivered 67 technical presentations. The Laboratory also publishes the Lincoln Laboratory Journal, a compendium of current research performed by Laboratory staff. This year's issues emphasized the themes of aviation research and integrated sensing and decision support.

Summary

The demand for the Lincoln Laboratory's research contributions remains very strong. The programs cover a broad spectrum, from fundamental investigations to developmental engineering, and there is a healthy diversity in the sources of sponsorship. The prototyping efforts in the Laboratory have experienced significant growth over the past few years, indicative of the Laboratory's critical roles in technology development and transfer of knowledge to industry. The increase in development programs has been valuable to the recruitment of new talent to the Laboratory. The realignment of some missions to address emerging DOD concerns and the addition of strategically focused new offices and a service department have positioned the Laboratory to provide the research and engineering support critical to new demands made on MIT's mission of service to the nation.

Eric D. Evans
Director

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