Lincoln Laboratory

Lincoln Laboratory, a federally funded research and development center (FFRDC) operated by the Massachusetts Institute of Technology, is also designated a Department of Defense (DoD) Research and Development Laboratory. Operating under a prime contract with the Department of the Air Force, Lincoln Laboratory conducts research and development pertinent to national security 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 that the government cannot acquire through in-house or private-sector resources.

For the 2009 federal fiscal year, Lincoln Laboratory is projected to receive approximately $741 million that will support the efforts of approximately 1,400 professional technical staff, 300 technical support personnel, and 960 support personnel; outside procurement will exceed $360 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, and the National Oceanographic and Atmospheric Administration. In addition, Lincoln Laboratory carries out noncompetitive research with industry under approved Cooperative Research and Development Agreements and other collaborative activities with academic institutions.

On April 1, 2005, the Department of Defense 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 58 years, Lincoln Laboratory has provided advanced technological solutions to meet national security needs, earning a Secretary of Defense Medal for Outstanding Public Service in 2001 for its half-century of distinguished technical innovation and scientific discoveries.

Laboratory Operations

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

Organization

Lincoln Laboratory's success has been built on the core values of technical excellence, integrity, and innovation, all of which are exemplified by the Laboratory's exceptional staff. The three-tiered organizational structure—Director's Office, divisions and departments, and groups—encourages interaction between staff and line management. Increasing demands to conduct research and development of more complex, integrated systems have raised the level of collaboration between staff and services. Service departments, as providers of standardized support, enable cross-divisional research teams to focus on technical challenges rather than on administrative services.

Key Changes to the Laboratory's Senior Management

- Dr. Marc D. Bernstein was appointed associate director of MIT Lincoln Laboratory
- Dr. Steven R. Bussolari was appointed to the Director's Office staff, responsible for strategic initiatives
- John E. Kuconis was appointed executive officer, Director's Office staff
- Dr. Bernadette Johnson was appointed chief technology officer
- Dr. Eliahu H. Niewood was appointed head of the Engineering Division
- Dr. Hsiao-hua K. Burke was appointed head of the Air and Missile Defense Technology Division
- Dr. Israel Soibelman was appointed associate head of the Air and Missile Defense Technology Division
- Dr. Craig L. Keast was appointed associate head of the Solid State Division
- Lee O. Upton, Joyce D. Yaffee, and William M. Brown stepped down from the Steering Committee
- Zachary J. Lemnios left Lincoln Laboratory to accept a presidential appointment as director of Defense Research and Engineering

Key Changes to the Laboratory Service Departments

- Cheryl L. Overs joined Lincoln Laboratory as head of the Financial Services Department
- Kerry A. Harrison was appointed assistant head of the Human Resources Department
- Joseph Dolan was named assistant head of the Facility Services Department

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

Staff

Key to maintaining excellence at Lincoln Laboratory is the quality and diverse talents of its staff. Sixty-five to 75 percent of the Laboratory's new staff are hired from the nation's leading technical universities. The Laboratory conducted on-campus interviews at over 50 universities this past year, and a number of women's colleges and colleges historically comprising minority students were added to the recruiting calendar. The makeup of the Laboratory staff by degree and academic discipline is shown in figures 2 and 3.

Professional technical staff	1,411
Total employees	2,673

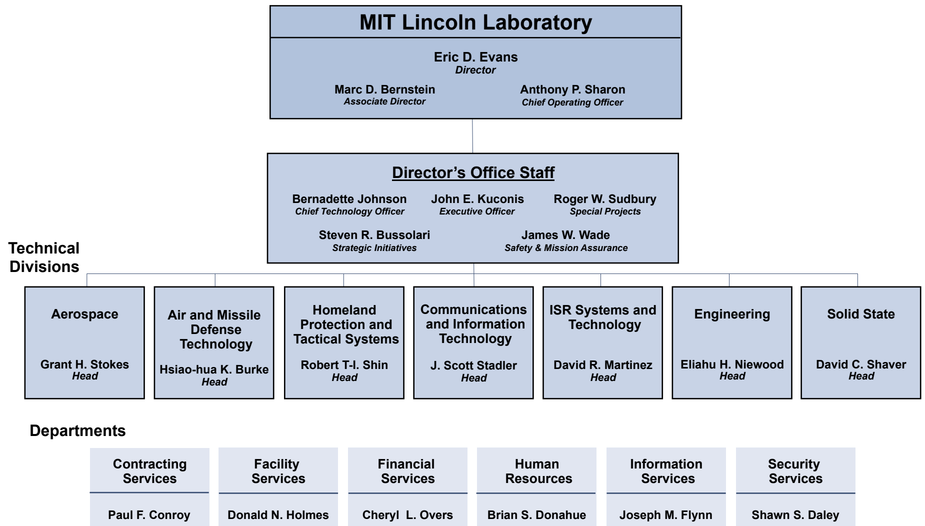

Figure 1. Lincoln Laboratory's organizational structure

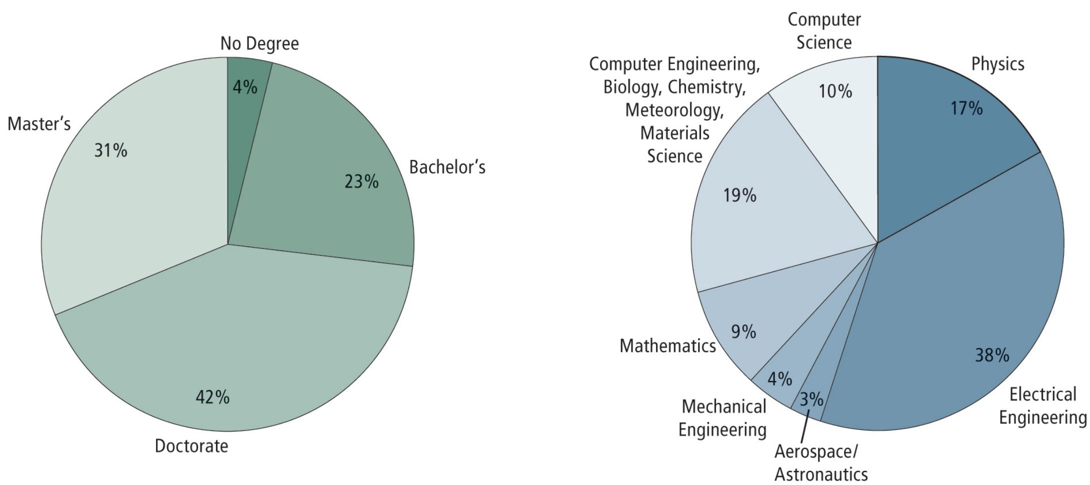

Figure 2. Composition of professional staff by academic degree (left) and academic discipline (right)

Honors and Awards

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

- Dr. Grant H. Stokes was presented with the Air Force Meritorious Civilian Service Award for his service on the Air Force Scientific Advisory Board
- Dr. R. Louis Bellaire received the Secretary of Defense Medal for Outstanding Public Service for his service to the Missile Defense Agency
- Dr. William J. Blackwell received the 2009 NOAA–David Johnson Award for his outstanding, innovative use of Earth-observation satellite data
- Dr. Michael S. Brandstein and Dr. Darryl P. Greenwood were named fellows of the *Institute of Electrical and Electronics Engineers* (IEEE)

- Dr. John J. Zayhowski was named a fellow of the Optical Society of America
- Dr. Benny J. Sheeks and Allen D. Pillsbury received MIT Lincoln Laboratory Technical Excellence Awards
- Dr. Marilyn M. Wolfson and Dr. James E. Evans received the First Place Technical Writing Award from the Air Traffic Association for their journal article on air traffic management technology
- Dr. Clifford J. Weinstein, Dr. William M. Campbell, Dr. Brian W. Delaney, and Gerald O'Leary received the IEEE Aerospace Conference Best Paper Award for their paper on techniques for counterterror social network analysis and intent recognition

Professional Development

Lincoln Laboratory's commitment to the professional development of its staff is evinced by the variety of onsite courses offered in technical fields, computing, and management skills. During this past year, the Technical Education Program offered semester-length courses taught by Lincoln Laboratory technical staff or by an MIT professor:

- Analog Bipolar Circuit Design
- Net-centric Operations
- Signal Processing for Ballistic Missile Defense
- Feedback Circuit Techniques

This year, Lincoln Laboratory initiated online courses. The first two opencourseware offerings, Introduction to Radar Systems and Adaptive Antennas and Phased Arrays, are video lectures with accompanying PowerPoint slides. Both courses are available on the Laboratory's external website, http://www.ll.mit.edu/.

The Training and Development Program sponsored courses in MATLAB techniques, management techniques, and scientific and technical writing. Fabrication Training Courses, a new series, will begin in July 2009 with sessions on polymeric applications and electrostatic discharge. Division and staff seminars on current research continued to be presented every week, and special seminars are often brought to the Laboratory.

In addition, the Laboratory encourages its staff to pursue advanced education. For highly qualified candidates, the Laboratory offers the opportunity to apply to the Lincoln Scholars program that supports the pursuit of advanced degrees. This year, under the Lincoln Scholars program, one staff member earned a doctorate and eight earned master's degrees, primarily in electrical engineering and computer science; for FY2010, 31 advanced-degree candidates are enrolled in the Lincoln Scholars program. Additionally, 17 Lincoln Laboratory staff members completed master's degrees and 3 completed doctorates at area universities.

Technical Program Highlights

Research at the Laboratory focuses on national security problems in diverse areas: tactical and intelligence, surveillance, and reconnaissance systems technology; air and missile defense; space situational awareness; biological-chemical defense;

communications and information technology; 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 FY2009, the Laboratory has been working on approximately 500 sponsored programs that range from large-scale hardware projects to small seedling initiatives. Notable highlights for each mission area, as well as future directions, are listed below.

Space

Principal 2009 Accomplishments

Development of the Space Surveillance Telescope has been completed, and the system is being evaluated at its site on the White Sands Missile Range in New Mexico prior to its transition to operational status (see figure 4).

Figure 4. The Space Surveillance Telescope will provide advanced ground-based optical system capability to enable detection and tracking of space objects.

The Extended Space Sensors Architecture, a net-centric test bed for space situational awareness, now provides real-time radar imagery of satellites to military users.

Optical Processing Architecture at Lincoln (OPAL), which provides mission planning and data processing for space surveillance sensors, has reached a mature stage of development. Deliveries of the OPAL system have been completed to a number of sensor installations.

Advanced technologies and processing techniques for future NOAA missions continue to be developed and demonstrated. The focus is on improving the design of new flight instruments.

Future Outlook

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

Lincoln Laboratory is pursuing several initiatives in the space area that include the next generation of sensor systems and downstream processing/information-extraction systems, such as:

- Sensor systems with new capabilities
- A small-aperture, space-based space surveillance system to provide wide-area search of the geosynchronous belt every 90 minutes
- Net-centric machine-aided decision support algorithms to allow the operators in the Joint Space Operations Center to react to emerging threats to space assets

Air and Missile Defense Technology

Principal 2009 Accomplishments

Lincoln Laboratory, in cooperation with the Australian Defence Science and Technology Organisation, completed demonstration of critical components of a next-generation over-the-horizon (OTH) surveillance radar using modifications to the Australian operational Jindalee OTH Radar Network. New radar waveforms and adaptive processing techniques were developed and utilized to significantly reduce the effects of multiple propagation paths on target detection. The technology is being integrated by the Laboratory into a radar test bed for the next-generation US OTH radar.

The Laboratory has been working on the development of net-centric, service-oriented software and hardware architectures. Sidecars (adjunct processors that add capability while not interfering with other sensor processors and software) are a key enabling technology for this effort.

Figure 5. The Reagan Test Site on Kwajalein Atoll in the Marshall Islands

Modernization of the sensor systems at the Reagan Test Site continues (see figure 5). Net-centricity is a significant goal for future operations.

Future Outlook

In keeping with its tradition of providing research and development for the US air defense, Lincoln Laboratory is strengthening this mission area.

The Laboratory will be working 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.

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

Communications and Information Technology

Principal 2009 Accomplishments

In a five-month rapid development effort, Lincoln Laboratory modeled, designed, built, integrated, and fielded two custom 2.7 gigabaud (2.7 billion symbols per second) laser communications (lasercom) terminals at field sites located in the western suburbs of Boston and separated by 5.4 kilometers of wooded countryside (see figure 6). This effort, which culminated with data collection throughout much of September 2008, verified high-availability communications over the link by using modest, eye-safe levels of optical power.

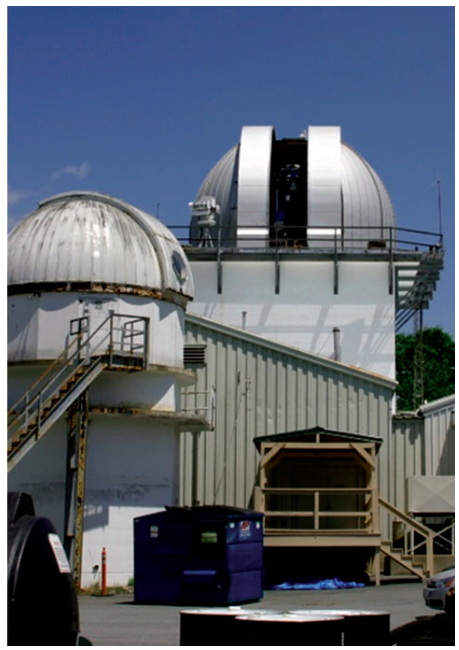

Figure 6. The receive site for the lasercom demonstration was the telescope dome at the Laboratory's Firepond facility in Westford, MA. The transmit and receive sites were chosen on the basis of simulations that identified ground-to-ground links that would experience the desired turbulence.

Lincoln Laboratory continued its successful testing of protected military satellite communications by flying the first Advanced Multiband Communications Antenna System delivered to the government. The new antenna system, designed for wide-body aircraft, flew on the Paul Revere, a heavily modified Boeing 707 the Laboratory operates as a communications and sensor testbed used in the development of integrated networking and airborne sensing. A June 2009 flight test represents the most recent phase in Lincoln Laboratory's secure extremely high frequency satellite communications testing program.

A Laboratory-developed net-centric software toolkit enabled the rapid deployment of multisensor applications. This toolkit was demonstrated in a cross-mission scenario, showing how space situational awareness and missile-defense assets could be employed cooperatively.

Lincoln Laboratory has begun developing a laser communications system that will demonstrate high-data-rate communications between a lunar-orbiting NASA satellite and a ground site in the United States. The Lunar Laser Communications Demonstration will address NASA's need for very-high-rate, very-long-distance communications systems that are small enough to fly in space.

Future Outlook

Lincoln Laboratory will use the interim payload command-and-control capability to support the initial operation of the Advanced Extremely High-Frequency satellite.

Increased data rates and improved high performance are goals for lasercom technology.

Development and deployment of advanced computer network attack and analysis tools will be undertaken to evaluate the robustness of current and future DoD systems.

Intelligence, Surveillance, and Reconnaissance Systems and Technology

Principal 2009 Accomplishments

Lincoln Laboratory conducted a large-scale surface surveillance experiment with multiple airborne sensors, including electro-optic imagers and moving-object indication radars. The objectives were to assess the feasibility of detecting and tracking difficult objects moving between open rural areas and cluttered urban environments, and to develop the required processing techniques and multiple-sensor data-fusion and handover concepts.

Lincoln Laboratory researchers are developing 3D laser detection and ranging (ladar) imaging prototypes for simultaneous imagery and wide-area mapping of urban areas (see figure 7).

Figure 7. Ladar prototype system within the aircraft

Lincoln Laboratory developed new passive sonar beamforming algorithms for submarine bow sphere arrays. The new approaches have demonstrated significant benefits with recorded fleet data, and the Laboratory is working closely with the Navy and industry on algorithm technology transition into the Navy's submarine fleet.

The Lincoln Laboratory Grid (LLGrid), a large-scale, interactive on-demand parallel computing system, demonstrated a 0.5 petabyte calculation on the HPC Challenge STREAM benchmark; this is one of the largest single problems ever run on a computer. LLGrid has expanded to more than 300 users. In June, the Department of Defense's High Performance Computing Modernization Program awarded Lincoln Laboratory a supercomputer for developing novel sensor processing algorithms using LLGrid.

In support of transitioning technology and sharing technology developments, Lincoln Laboratory hosted the High Performance Embedded Computing and the Intelligence, Surveillance, and Reconnaissance Systems and Technology workshops.

Future Outlook

Lincoln Laboratory is developing imaging sensors, automated processing algorithms, and processor technologies to improve the capabilities of persistent electro-optical systems for the Army and other agencies.

Overland and maritime ISR exploitation techniques are being developed for next-generation airborne and space-based radars.

Miniaturized digital receivers and sensor payloads are in development for small unmanned aerial vehicles and high-performance wideband passive geolocation.

Advanced Electronics Technology

Principal 2009 Accomplishments

A unique device called the orthogonal transfer array was developed for the Air Force's Panoramic Survey Telescope and Rapid Response System (Pan-STARRS), which is a fast sky-survey system comprising four telescopes, each with a 1.4 gigapixel focal plane array (FPA). The first 1.4 gigapixel FPA was integrated into a recently constructed wide-field-of-view 1.8 m aperture telescope, which went operational in December 2008.

The Laboratory's unique 3D integrated-circuit technology was used to demonstrate functional 4-side-abuttable imaging modules for large "mosaic" focal plane arrays. In this architecture, the electronics for each pixel reside in tiers behind the high-fill-factor photodetection tier, enabling many key improvements, such as integration of multiple material and process technologies for optimized functionality.

Cryogenic Yb:YAG laser technology has been demonstrated in a laboratory prototype as a high-power illuminator. Operation with liquid-nitrogen cooling (–320°F) improved lasing efficiency and reduced thermo-optic distortions, thereby resulting in more than double the pulse energy in a higher-quality laser beam compared to a room-temperature device. Engineering of an illuminator for field system tests has been completed.

The Advanced Imaging Technology Group at Lincoln Laboratory has fabricated arrays of new high-fill-factor Geiger-mode avalanche photodiodes (GM-APDs) for application as optical wavefront sensors (see figure 8). High-quality wavefront sensors are key enablers for laser communications and high-resolution astronomy.

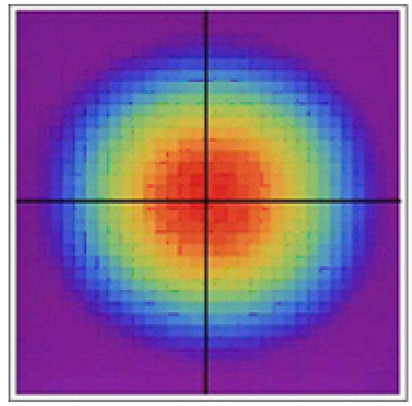

Figure 8. This is a false-color contour plot of the total number of detection events from all four detectors in a quad cell as a function of the location of a small light spot. (Red denotes high counts; blue, low counts.) Photoelectrons incident on the boundary areas between adjacent APD regions are collected and detected smoothly, demonstrating that this design is well suited for wavefront sensor use.

Future Outlook

Additional applications will emerge in three general areas: (1) imaging and radio frequency technologies in support of the intelligence community, (2) laser technologies in support of communication and targeting systems, and (3) cryoelectronics for longer-term impact in infrared sensing and high-speed computation.

The following are some specific focuses:

- There is continued work on Geiger-mode single-photon detection technology. The range of applications for this technology continues to expand, from laser radar to communication and passive low-light-level imaging.
- The use of the slab-coupled optical waveguide structure continues to provide significant performance improvements in a variety of device structures optimized at different wavelengths and for different applications, from coherent combining of laser arrays to amplifiers for low-noise oscillators.
- The more mature microchip solid-state laser continues to find broad application in DoD systems, with optimized sources recently deployed in both laser radar and biosensing systems.

Homeland Protection

Principal 2009 Accomplishments

Lincoln Laboratory continued its support of the Enhanced Regional Situation Awareness (ERSA) system for homeland air defense around the National Capital Region. Significant sensor improvements to ERSA include installing the theater Enhanced Target Range and Classification Sentinel Radar on Katahdin Hill at Lincoln Laboratory and collecting data. A technical interchange with the Aviation and Missile Research, Development, and Engineering Center Program Office was held to review results and strategies for modifying this theater system to meet the needs for homeland defense.

The Laboratory is applying its national security expertise to assist federal, state, and local government agencies to respond to and manage large-scale disasters such as hurricanes, earthquakes, and forest fires. Working with the California Department of Forestry and Fire Protection (CAL FIRE) and the Riverside County Fire Department, Lincoln Laboratory engineers are collecting data to understand the challenges and issues that arise during management of large-scale wildfires (see figure 9).

In support of the Department of Homeland Security (DHS), the Laboratory initiated measurements/analysis of the feasibility of rapid detection of biological and chemical threats in shipping containers.

Lincoln Laboratory is participating in a consortium effort to design tools that simplify the process of securing critical infrastructures.

Figure 9. Lincoln Laboratory's Fire Management Team observed operations during a wildfire near Santa Barbara, CA, in July 2008.

Future Outlook

The Laboratory is initiating efforts toward the goal of an integrated air, land, and maritime surveillance architecture for homeland security/defense.

Lincoln Laboratory foresees work relating to architecture development for urban biodefense, as well as test and evaluation of biological and chemical early-warning systems for facility defense, including buildings of military and civilian significance.

Transition of rapid biological trigger technology to the DoD and DHS is expected.

The Laboratory will apply its analytical expertise and systems perspective to provide support for customs and border protection missions.

Tactical Systems

Principal 2009 Accomplishments

Lincoln Laboratory conducted a comprehensive assessment of options for US Air Force airborne electronic operations. This assessment included systems analysis of various proposed options, development of detailed models of surveillance radars and their electronic protection systems, and testing of various electronic systems and surveillance radars.

A number of assessments were performed examining the impact of exporting advanced military systems. These assessments were used by the Office of the Under Secretary of Defense for Acquisition, Technology and Logistics and by Congress as part of the decision-making process for a number of major export programs.

Countermeasures to several counterinsurgency devices were assessed and tested. Devices were measured and analyzed to understand their behavior and to determine exploitable characteristics. A number of exploitation approaches were laboratory tested, and the results of these tests were used to assess the viability of concepts of operations employing these approaches.

The Laboratory demonstrated an advanced signals-intelligence receiver designed for counterterrorism applications. The multichannel receiver is unique to this application in its use of adaptive beamforming to suppress interference sources and to preserve receiver sensitivity (see figure 10). The receiver system, along with a custom-built antenna array, was flight tested.

Figure 10. Lincoln Laboratory developed and successfully tested this multichannel signals intelligence receiver, which has enabled the Laboratory to rapidly innovate, develop, and test novel sensor capabilities for a variety of critical national problems. Key features include low noise figure, wide bandwidth, and direction-finding capability.

Future Outlook

The Laboratory will continue to play an important role in helping the US Air Force develop advanced electronic protection systems and will continue to develop new systems to evaluate future air defense threats. One planned effort is to use an existing passive surveillance system as a baseline for examining the impact of potential advanced signal processing techniques on passive system performance.

The Laboratory will also continue the development of an advanced electronic operations test bed aircraft. This aircraft will be used primarily to support testing of the electronic protection features of US aircraft radars. This test bed will also be used in the development of advanced electronic protection.

Lincoln Laboratory is planning continued enhancements of its rapid development capabilities to address needs in counterterrorism and other applications. The Laboratory's broad technical expertise and its agility in assessing and prototyping novel and complex systems strongly position the Laboratory to rapidly respond to DoD needs. The greater use of software-defined systems, activities to better understand and exploit consumer electronics, and dedicated rapid innovation facilities are being planned to further enhance the Laboratory's ability to rapidly develop systems.

Air Traffic Control

Principal 2009 Accomplishments

The Laboratory-developed Corridor Integrated Weather System (CIWS) was reengineered to provide continental US (CONUS-wide) coverage and a robust configuration suitable for handoff to the Federal Aviation Administration (FAA) for long-term operation.

The Runway Status Lights system continues successful operation at Dallas/Fort Worth International Airport. The system was expanded to additional runways. The FAA has announced that Logan International Airport in Boston will be one of the first airports in the United States to deploy Runway Status Lights (see figure 11).

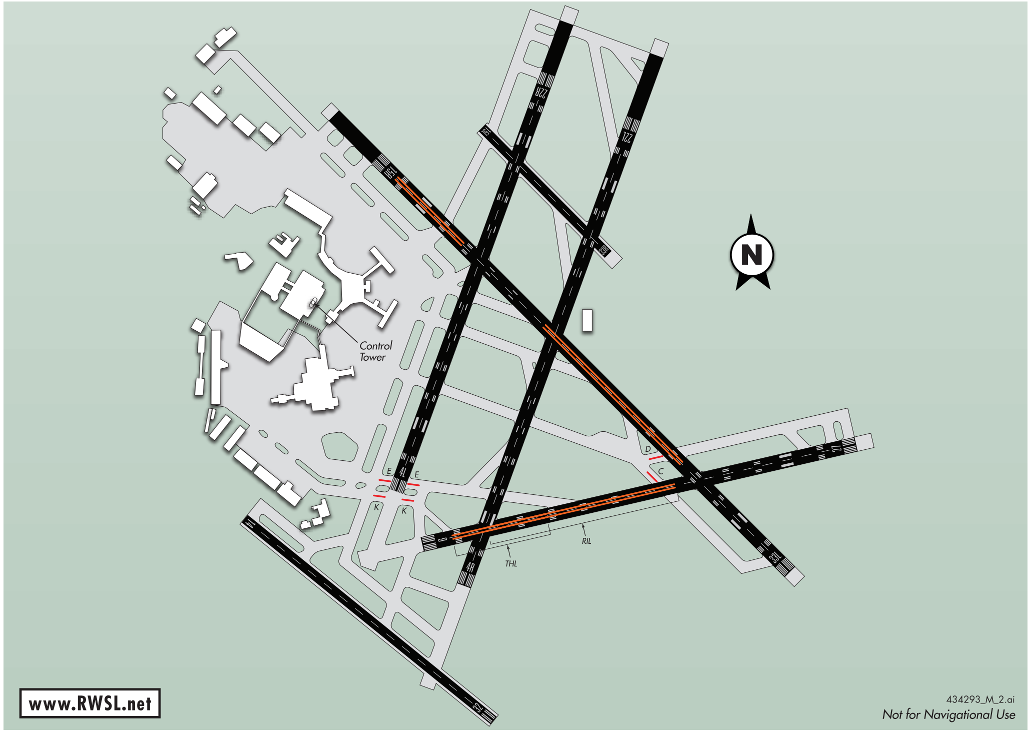

Figure 11. Airport diagram of Boston's Logan International Airport with runway intersection lights, takeoff hold lights, and runway entrance lights (in red).

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

The Laboratory is working with the FAA to refine concepts for a next-generation Multifunction Phased Array Radar that would provide the surveillance services currently acquired from separate ATC and weather radar networks.

Based on successes at Lincoln Laboratory, the FAA has begun fielding a national monitoring program to assess and improve the performance of the Traffic Alert and Collision Avoidance System (TCAS) across the United States.

Future Outlook

A modern FAA communications architecture will encompass sensor data, decision-support applications, and efficient sharing of information among the decision makers involved in operating the National Airspace System.

Over the next few years, Lincoln Laboratory will continue operating, monitoring, and upgrading CIWS, which is still considered a prototype. The FAA is planning to transition the system to the agency's William J. Hughes technical center in Atlantic City, NJ, in 2011 with help from the Laboratory. At that point, CIWS will no longer be operated by the Laboratory as a prototype and will be recognized as a formal part of the US National Airspace System, which handles the flow of the nation's air traffic.

Increased emphasis is being placed on the development and testing of next-generation paradigms for aircraft-separation assurance on the airport surface and during flight. This effort includes evolution of deployed collision-avoidance technologies such as TCAS and Runway Status Lights, as well as simulation, analysis, and robustness testing of future concepts.

Laboratory researchers are adjusting the Route Availability Planning Tool—which takes weather information from satellites and radar systems, makes predictions about whether a pilot would choose to fly through such conditions, and displays the information graphically to enable an air traffic controller to make a quick decision—to take more account of the impact of arrivals on the system.

Collaboration with MIT Campus

Lincoln Laboratory participates in the 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 Alan S. Willsky. The Lincoln Laboratory/MIT Campus Seminar Series, a program that promotes an exchange of innovative research ideas, is in its third year. During FY2009, five speakers from MIT gave talks at Lincoln Laboratory, and seven researchers from the Laboratory spoke at the campus. Seminar topics ranged from digital focal plane array technology to the Laboratory's Slab-Coupled Optical Waveguide Laser (SCOWL) to artificial intelligence.

One of our most valued ties to the campus is the exceptional alumni who join the Laboratory. This year, 20 MIT alumni became staff members at Lincoln Laboratory.

Integrated Photonics Initiative

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

Advanced Concepts Committee

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. In 2009, the ACC funded 14 projects; listed below are some representative projects to illustrate the breadth of research undertaken through this initiative (* denotes an MIT researcher):

- Optonanomechanical self-adaptive photonic devices based on light forces
  Researchers: D. Caplan, M. Popovic, * P. Rakich
- Rapid DNA fingerprinting
  Researchers: L. Parameswaran, E. Schwoebel

- Compact power-efficient high-performance WDM transmitters
  Researchers: D. Caplan, M. Popovic, * S. Spector
- Development of improved bacteria for bioremediation of chemical warfare agents and other toxins
  Researchers: M. Petrovick, K. Prather*
- Geostationary microwave array spectrometer (GEOMAS)
  Researchers: W. Blackwell, R. Leslie, J. Seeley, M. Shields, D. Staelin*
- Practical and fast secure connection establishment in tactical networks
  Researchers: R. Khazan, J. Cooley
- A through-the-wall radar video camera
  Researchers: G. Charvat, T. Ralston, J. Peabody

The ACC also sponsors the Defense Studies Seminar Series. This year's speakers included Fotini Christia, assistant professor of political science and a member of the Security Studies Program at MIT; Daryl Press, associate professor at Dartmouth College and a member of MIT's Security Studies Program; and Colin Jackson, assistant professor at the Naval War College.

Industrial Liaison Program

The Laboratory supports activities conducted by the Industrial Liaison Program staff through presentations by Laboratory staff on cooperative research and development opportunities and technical licensing options.

Technology Transfer

Lincoln Laboratory's focus on adapting and demonstrating advanced capabilities to enhance existing systems results in important technology transfer opportunities. The mechanisms for transferring Lincoln Laboratory–developed technology to industry, academia, and government include briefings and technical publications; delivery of hardware, software, algorithms, or advanced architecture concepts to government contractors under the auspices of a government sponsor; Small Business Technology Transfer (STTR) projects, which are joint research partnerships with small businesses; and Cooperative Research and Development Agreements (CRADAs), which are privately funded by businesses to transfer the Laboratory's technology.

Lincoln Laboratory's deliveries of hardware, software, algorithms, and advanced architecture concepts to government contractors included the following:

- Lincoln Laboratory's fully depleted silicon-on-insulator complementary metal-oxide semiconductor process technology has been used by over 60 different US industry, university, and government laboratories to fabricate more than 150 different circuits as part of 10 multiproject runs performed in the Microelectronics Laboratory.
- Lincoln Laboratory's silicon and indium phosphide Geiger-mode avalanche photodiode (APD) technologies were used in Jigsaw and other Defense Advanced Research Projects Agency and DoD prototype systems.

- A spherically curved, 1.2-billion-pixel, ultra-low-noise, orthogonal transfer array, silicon charge-coupled device imager was delivered to the Pan-STARRS operated by the University of Hawaii's Institute for Astronomy.
- The Laboratory transferred to industry the weather-sensing algorithms for the Terminal Doppler Weather Radar, which is used by air traffic controllers nationwide.

Among the STTR projects this year were evaluations of the nonlinearities of high-temperature superconducting thin films and the development of a sparse-aperture phased-array antenna. In FY2009, the Laboratory participated in 10 CRADAs with local government and business organizations; these projects included biosensor development, geosynchronous communications satellite encounter analysis, and research in semiconductor lithography.

Working through the MIT Technical Licensing Office, the Laboratory has made 29 technology disclosures, applied for 16 US patents, and was awarded 7 US patents between July1, 2008 and June 30, 2009.

Dissemination of Technology/Technical Education

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. Listed below are some of these workshops and seminars:

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

Publications

Knowledge dissemination is also achieved through the many venues in which Lincoln Laboratory researchers publish. The technical staff publishes articles in peer-reviewed journals; in the past year, 76 technical articles were published by Laboratory staff in professional journals. Staff members also attended national technical conferences such as the IEEE Military Communications Conference and the annual meeting of the IEEE Lasers and Electro-Optics Society. In FY2009, 56 technical presentations by Laboratory staff were included in the proceedings of major public conferences. In addition, members of the technical staff author books and contribute chapters to collaborative textbooks. In the past year, *Parallel MATLAB for Multicore and Multinode Computers* by Jeremy Kepner of the Embedded Digital Systems Group and Adaptive Antennas and *Phased Arrays for Radar and Communications* by Alan J. Fenn of the Advanced RF Sensing and Exploitation Group were published. The Laboratory itself publishes the *Lincoln Laboratory Journal*, which contains comprehensive articles on current major research as well as journalistic pieces highlighting novel projects.

Partnerships with Universities

Lincoln Laboratory continues to promote technical education and knowledge exchange through partnerships with local universities. This year, under the sponsored research program, Lincoln Laboratory hosted 68 graduate and 45 undergraduate students. Under collaborative programs with MIT, the Laboratory hosted four MEng students from Course 6-A and 10 undergraduates through the Undergraduate Research Opportunities Program. In an ongoing partnership with Worcester Polytechnic Institute, seven WPI seniors completed qualifying projects for their major at Lincoln Laboratory.

Also this year, seven Lincoln staff members are enrolled in a new graduate-school-level, distance-education program in software engineering developed by Carnegie Mellon University's School of Computer Science. During a two-year period, these staff work full time at the Laboratory while completing five core courses, four elective courses, and a two-semester software engineering practicum. The distance education students are awarded an MS degree in information technology–software engineering (MSIT–SE) upon completion of their program. Next year, 11 Lincoln Laboratory staff members will be enrolled in the MSIT–SE program.

A collaboration with Tufts University's Department of Electrical and Computer Engineering has allowed three students to carry out research projects at the Laboratory. In addition, 51 students from various schools were employed at Lincoln Laboratory: 20 from Northeastern University, 13 from the Wentworth Institute of Technology, 9 from Rochester Institute of Technology, 3 from Rensselaer Polytechnic Institute, 2 from the University of Massachusetts at Amherst, 2 from New Mexico State University, 1 from Purdue University, and 1 from Champlain College.

Conservation

Lincoln Laboratory is committed to a workplace environment that is energy-efficient, follows best practices for sustainability, and approaches a zero carbon footprint.

This spring, a conservation study committee, appointed by the Laboratory's director, completed a comprehensive review assessing the status of the Laboratory's conservation measures, examining potential sustainability efforts, and recommending both long-term and short-term initiatives.

The Facility Services Department (FSD) has long been working to implement energy efficiency and conservation practices. Electricity consumption has been decreased through the addition of a variable-speed-driven chiller to the main chilled-water plant and the installation of energy-saving lighting fixtures in all new and renovated spaces.

FSD also has introduced "green" paper products in the cafeteria, eliminating nonbiodegradable styrofoam trays and food containers. Environmentally friendly cleaning products are used at the Laboratory, and the Laboratory's recycling efforts have been stepped up.

The Information Services Department is investigating energy-efficient hardware and software, and implementing a program to retire old, energy-consuming computers.

The Travel Office is working to expand participation in its commuter services programs. Shuttle service from Nashua, NH, was instituted, and 13 to 16 employees are using this service. The Travel Office has replaced one of its shuttle vans with a hybrid vehicle that gets better gasoline mileage and is looking into other vehicle replacements or modifications.

Recognizing that employee "buy-in" is vital to the success of conservation initiatives, the Laboratory has begun awareness activities. The first Green Day informational fair, held in October 2008, showcased conservation measures and eco-friendly products.

Community Outreach

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

Recognizing the importance of encouraging young people to pursue careers in science, technology, engineering, and mathematics, the LLCO has focused substantial attention on educational outreach. This year, over 2,500 local K–12 students, their parents, and teachers attended science demonstrations given by Laboratory technical staff through the *Science on Saturday* program. Topics covered in this year's demonstrations include rockets and flight; asteroids; lightning, tornadoes, and storms; "slime and flubber" (see figure 12); and acousto-electric musicology.

Figure 12. Dr. Andrew Siegel of the Laboratory's Advanced Space Systems and Concepts Group demonstrates how simple household ingredients combine to make a non-Newtonian fluid, a substance that acts like a liquid when being poured but like a solid when a force is acting on it. Dr. Siegel created oobleck, a non-Newtonian fluid that got its name from the "goo" that fell on the kingdom in a Dr. Seuss children's book.

Lincoln Laboratory's robotics initiative, Robotics Outreach at Lincoln Laboratory (ROLL), is in its second year. ROLL takes advantage of the current popularity of robotics to interest students between the ages of 9 and 17 in science and technology. ROLL hosts robotics workshops at the Laboratory, sponsors teams in FIRST (For Inspiration and Recognition of Science and Technology) competitions, and provides technical mentors to local area schools and groups. After placing first in a state-wide FIRST tournament, a Laboratory-mentored team of 15- to 18-year-old students competed in the 2009 FIRST Technical Challenge World Championship in Atlanta, Georgia, where it finished 24th out of 100 teams.

Technical staff volunteers have given classroom presentations at local-area elementary, middle, and high schools, delivering presentations on science and engineering to more than 6,000 students. As a partner in the regional Leadership Initiatives for Teaching and Technology (LIFT^2) program, which provides summer employment opportunities for math and science teachers, Lincoln Laboratory hosted two high-school teachers. A math teacher working with the Surveillance Systems Group helped with the Runway Status Lights project, and the other, a math and computer science teacher, worked with the Information Services Department's web team.

In community-service initiatives this year, the LLCO divided proceeds from events such as a used book drive/sale between the United Way and the MIT Community Service Fund. The LLCO continued promoting participation in the benefit bike/hike event for the Multiple Sclerosis Society, raising over $10,000. The ongoing campaign to collect and mail food, toiletries, and books to US soldiers overseas was expanded to include the collection of clothing for children in Iraqi and Afghanistani villages where US troops are stationed.

Summary

The demand for Lincoln Laboratory's research remains strong. Current programs cover a broad spectrum, from fundamental investigations to developmental engineering, and the sources of sponsorship are diverse. Emerging national concerns are leading to more opportunities for research and development in areas such as biological-chemical sensing, network security and information assurance, net-centric capabilities for systems, alternative energy approaches, and integrated sensing and decision support. Prototyping efforts continue to experience significant growth, and expansion in development programs has been valuable to the recruitment of talented technical staff members. The Laboratory is working to strengthen its technology transfer activities and, complementary to that goal, to improve external communications. Community outreach efforts continue to provide resources to outside communities, with educational programs being particularly successful. Ongoing improvements to support engineering, administration, and infrastructure are enhancing the Laboratory's ability to achieve its mission. In conclusion, Lincoln Laboratory is well positioned to take on the challenges and responsibilities inherent in its mission to be of service to the nation.

Eric D. Evans
Director

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