Lincoln Laboratory

Lincoln Laboratory is a federally funded research and development center laboratory operated by MIT for the Department of Defense (DOD). The mission of the laboratory is the advance of technology in support of national security. Research and development are carried out in three core areas: sensors, signal processing, and communications supported by a broad research base in advanced electronics.

For the federal fiscal year 2004, Lincoln Laboratory received $595 million that supported the efforts of 1,300 professional technical staff and 1,200 support personnel. While most of the research is sponsored by the DOD, research funding is also received from the Federal Aviation Administration, the National Aeronautics and Space Administration (NASA), and the National Oceanographic and Atmospheric Agency. In addition, Lincoln Laboratory also carries out noncompetitive research with industry under approved cooperative research and development agreements.

Laboratory Operations

Laboratory operations are marked by fundamental attributes: high-caliber staff, first-rate support personnel, a flat organizational structure, a strong alignment with the MIT campus, and high-quality technical facilities and infrastructure.

Organization

The laboratory's performance depends on the creativity of its technical staff. The flat organizational structure (see Appendix A), consisting of three levels—the Director's Office, divisions, and groups—encourages the exchange of ideas between staff and line management. There has been an increasing demand upon the laboratory to conduct research and development of more complex, integrated systems. The nature of this work has raised the level of sharing and integration among staff, facilities, and services. In response, the laboratory has restructured its organization, creating service departments as providers of standardized support and aligning technical divisions as stewards of specific mission areas, sponsors, and core competencies. Standardized support allows research teams staffed from across the divisions to quickly draw on key services and permits them to focus on the technical challenges. The new service departments for Administrative Services, Human Resources, Security Services, and Information Services began operation in December of 2003. The new laboratory structure is depicted in the figure. The following individuals were appointed heads of the new service departments:

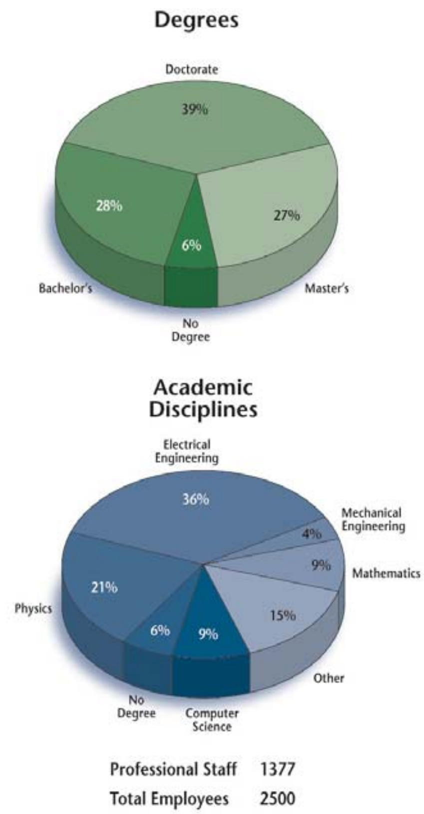
- David Woodbury, head, Administrative Services
- Brian Donahue, head, Human Resources
- Shawn Daley, head, Security Services
- Gerald Banner, head, Information Services

Key changes to the laboratory’s senior management team include the retirement of Mr. Ray LaFrey and the appointment of Dr. Steven Bussolari as assistant head of the Tactical Systems Technology Division. Dr. John Tabaczynski and Mr. Alan Bernard relinquished their Steering Committee assignments and were appointed principal laboratory researchers.

Staff

A key factor in maintaining excellence at Lincoln Laboratory is the quality of its staff. The laboratory obtains 60–75 percent of its new staff directly from the leading technical universities in the nation. We 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 the accompanying figure.

In addition to its on-campus recruiting efforts, the laboratory maintains a vibrant program of fellowships, interns, cooperative work-study, and research assistant programs at both the graduate and undergraduate levels. This year, under the sponsored research program, we hosted 32 graduate and 28 undergraduate students. Specific to MIT, the laboratory hosted 10 6-A students and four sponsored undergraduates. We also have an ongoing collaboration with the Worcester Polytechnic Institute to have a competitively selected group of seniors complete their major qualifying projects at Lincoln Laboratory. In addition, we accepted 29 students from Northeastern University’s cooperative study program.



Composition of professional staff at MIT Lincoln Laboratory.

To help its staff keep pace with the rapid changes in science and technology, the laboratory offers a program of on-site courses and for a select few the chance to pursue an advanced degree under the Lincoln Scholars program. Recently completed on-site courses include Feedback Control Systems, Introduction to Radar Systems, Laser Physics, Pattern Classification, and Parameter Estimation for Dynamic Systems. The Lincoln Scholars program currently has six doctoral candidates and 13 master’s candidates, primarily in electrical engineering and computer science. This year, five Lincoln Laboratory staff members completed their doctorates and four completed their master’s degrees, as indicated in the following table.

Close, Sigrid	PhD
Dain, Oliver	MS
Dolan, Peter	PhD
Dumanian, Audrey	PhD
Krigman, Steven	PhD
Silbovitz, Anna*	SM
Stimac, Andrew*	SM
Tyrrell, Brian*	SM
Watson, Jennifer*	ScD

*MIT Graduate

Laboratory staff members maintain close ties with their professional societies, serving as officers, symposia chairs, and committee contributors. This year the laboratory was pleased to announce that Roger W. Sudbury was elected as an Institute of Electrical and Electronics Engineers (IEEE) fellow, and Gerald F. Dionne was elected fellow of the American Physical Society. In addition, Grant H. Stokes was named Engineer of the Year by the New England Section of the American Institute of Aeronautics and Astronautics, and J. Barrie Billingsley received the Warren D. White Award for excellence in radar engineering from the IEEE Aerospace and Electronics System Society. Wade M. Kornegay was appointed to the Army Science Board for the Department of the Army. Each year the National Institute of Standards and Technology conducts an international evaluation for speech recognition technology. The Lincoln Laboratory team finished first out of a field of 23 participants. Evaluations were conducted under both regular and cellular telephone conditions using speech in Arabic, English, Mandarin, Russian, and Spanish.

In January 2004, the director, Dr. David L. Briggs, presented the laboratory’s Technical Excellence Awards to Robert A. Bond for his work in embedded-systems software technology and Richard M. Heinrichs for his work in laser radar technology. In June 2004, the recipients of the MIT Lincoln Laboratory Team Awards were announced: the New England Air Situational Awareness Demonstration Team led by Curtis W. Davis; the Airborne RF Systems Test Team led by Randy K. Avent and Joseph O. Chapa; the Speech Technology Team led by Clifford J. Weinstein; the Advanced Surveillance Technology Team led by James Ward and Geordi K. Borsari; and the SAP Project Team led by Ronald L. Hersey.

Support Staff

The support staff and the services they provide are integral to the technical operations of the laboratory. One of the key changes this year was the completion of an information technology roadmap and the formation of a dedicated Information Services Department. The roadmap outlined an information technology vision matched with the laboratory’s technical and support operations and included the framework for a strategic network initiative. Important elements of the roadmap include consolidated support, shared computer and data servers, remote staff collaboration, and interconnected secure enclaves. The Information Services Department was created to execute the IT roadmap and increase the emphasis on user-oriented services for communications, computing, library, and publishing resources. The premier accomplishment of the Information Services Department this year was the launch of the Systems, Applications, and Products in Data Processing (SAP) enterprise management system. Core administrative services have all been integrated under the SAP umbrella: finance, accounting, human resources, property and material, plant maintenance, and procurement. Included in this project was the system integration of the laboratory's finance and human resource systems with those of the campus. This was a comprehensive undertaking that touched virtually every aspect of laboratory activity and the entire staff.

Alignment with the Main Campus

Lincoln Laboratory uses a Campus Interaction Committee to strengthen its ties and alignment with the main MIT campus. The committee's principal focus is joint research and policy seminars and is chaired by Professor Dan Hasting. As a result, the laboratory staff was involved with 34 MIT graduate theses and participated in two courses and seven seminars on campus. Emerging collaborative areas include

- Electromagnetics: Professor Kong
- Decision Support: Professor Willsky
- Nanomanufacturing: Professor Chen
- Signal Processing: Professor Oppenheim

Another avenue for enhancing the laboratory's ties with the campus is through the Advanced Concepts Committee. The committee provides 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 practice. Current studies and research and development include

- Information theoretic sensor management
- Novel thermophotovoltaic devices
- Plasma ion mobility spectrometer

In addition, Professor Rajeev Ram has joined the committee.

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. With the help of the MIT Technical Licensing Office, the laboratory has made 33 technology disclosures, applied for 19 patents, and was awarded 26 patents.

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

Four staff members returned upon completing their graduate degrees under the Lincoln Scholars program. In the other direction, the laboratory's Dr. Karl Berggren has joined the MIT faculty.

Technical Facilities and Infrastructure

Rapidly changing technology and fast, new research opportunities demand a first-rate infrastructure. In addition, the high quality of our laboratories and research equipment serve as an incentive for attracting top technical talent. Four major infrastructure improvements were completed this year. First, an electro-optic test range was constructed to support efforts such as laser radar and imaging devices. Second, a space situational awareness center was developed to fuse data from worldwide sensors in near real time to support research on improved methods for tracking and identifying space objects. Third, a new communications laboratory was built to support optical communications research. And fourth, an RF system test facility was developed to support rapid prototyping and testing on the ground and in an airborne platform.

Our infrastructure also enhances the quality of life at the laboratory. The lab's Health and Wellness Center has recently completed a new addition to meet the increased patronage for organized exercise classes as well as for cardio-exercise machines. To improve food services for the staff, renovations to the main cafeteria have started.

Technical Program Highlights

Research at the laboratory focuses on national security tasks involving air defense, ballistic missile defense, space control, biological-chemical defense, communications and information technology, and advanced electronic technology. Two principal activities of the laboratory's technical mission are, first, the development of components and systems for experiments, engineering measurements, and tests under field operating conditions; and second, the dissemination of information to the government, academia, and industry.

Maximum dissemination of technical information is achieved through a series of annual technical seminars and the contribution of technical articles to peer-reviewed journals. Nine technical seminars were attended by over 2,500 researchers, engineers, and technical planning and policy administrators. Key seminars this year included the Advanced Electronics Technology Workshop, the High Performance Embedded Computing Workshop, the Adaptive Sensor Array Processing Workshop, and the Biological-Chemical Defense Seminar. In addition to the seminars, laboratory staff published 110 technical articles in professional journals. We also published two volumes of our own *Lincoln Laboratory Journal,* one of which was a thematic volume covering advances in hyperspectral sensing.

The laboratory has over 500 specific engineering development projects underway. Highlights follow for each of the major research areas.

Air Defense

A wide variety of work was carried out in air surveillance technologies, ranging from algorithmic development to system architectures. Advances in signal processing are being applied to radar and image processing applications through Lincoln Laboratory's C++ Parallel Vector Library (PVL). The PVL was created to support scalable, portable signal processing and, in particular, formed the nucleus of the Knowledge-Aided Sensor Signal Processing and Expert Reasoning architecture. This architecture employs processor software using a knowledge database to enhance processing for various radar applications.

Development is also underway to improve the capability of detecting slow-moving vehicles in both open terrain and under trees. Design and airborne testing of ultrahigh-frequency arrays is planned to meet a design goal for wide-area search and single-pass detection.

A prototype system architecture for homeland air surveillance, tracking, and identification was formulated and is currently moving into the demonstration phase. The design fuses multiple radar sources into an integrated air picture for the New England area. The ability to track low-altitude platforms was added through the installation of a short-range 3-D tracking radar on a tower. The output of this integrated air picture was successfully used to slave video cameras in real time to assist in aircraft identification.

Ballistic Missile Defense

This work involves technologies for sensing, tracking, and identifying ballistic platforms. One of the larger programs in this area is the Critical Measurements Program. The objective of this research is to develop the capability to detect and discriminate vehicles and objects rapidly transiting through space. A new Fly-Away Sensor Package (FASP) for collecting electro-optic and infrared focal-plane data on ballistic vehicles was completed. The FASP is released from a host spacecraft and flies in formation with the test objects to measure the performance of developmental sensors.

In addition to the sensor hardware projects, the laboratory continues its development of the radar open systems architecture, a unique approach to sharing live sensor data for algorithm development. The architecture has been installed at three test sites. Based on successful results to date, the transfer of this technology to industry partners has been accelerated.

Space Control

Approximately 25 percent of the laboratory's sponsored research is in space control. This work focuses on tracking and identifying objects in space as well as developing hyperspectral techniques for observing terrestrial features.

Work continues on advanced coherent/direct-detection laser radar (Ladar) under a new effort known as the Angle-Angle-Range-Doppler-Imaging Ladar. This device utilizes the same single-photon-sensitive array of avalanche photodiodes (APD) for both coherent and direct detection as well as a variable-pulse-format laser illuminator. These technologies have the potential to significantly enhance the capability of Ladar systems for object discrimination.

Extensive hardware system development was also started this year on two key passive optical surveillance projects. The first project was the development of a third-generation space-based surveillance system using 1,024 x 1,024 CCD arrays. The second project covers the design and build of a large field-of-view space surveillance telescope using a curved CCD focal plane. Also started this year was an upgrade to the Haystack radar system that will provide an order of magnitude improvement to the imaging resolution of objects in space.

Biological-Chemical Defense

The laboratory continues to combine the research efforts of biologists, chemists, and systems engineers to explore integrated systems for sensing biological and chemical threats to provide actionable information to decision makers. As part of the Cellular Analysis and Notification of Antigen Risks and Yields effort, the laboratory demonstrated dry B-cell storage with subsequent reconstitution and baseline performance at up to nine days. In a separate effort, work was successfully concluded on a measurements program addressing a subway, an arena, and an airport terminal, leading to documented findings on background and other conditions that affect a wide variety of potential biological or chemical agent targets.

The Army Research, Development, and Engineering Command has sponsored Lincoln Laboratory to apply its expertise in hyperspectral imaging for wide-area sensing of chemical agents dispersed over a wide geographic area. A system concept is being developed that may lead to an army-sponsored advanced concept technology demonstration. Complementary efforts with the Department of Homeland Security’s Science and Technology Directorate are being pursued to provide system approaches for civil applications.

Communications and Information

Significant contributions were made in advancing technology needed for the DOD’s new advanced wideband satellite communications systems. New power- and bandwidth-efficient RF waveforms developed at Lincoln Laboratory have become the basis of the needed RF capacity increase. For data rates above 1 Gbps, technology from our GeoLITE program for free-space optical communications is being incorporated into advanced standards and test beds. In addition, a large-scale hardware-in-the-loop network emulation has been created for evaluating new protocols that will support highly mobile networks.

A Mars communications link program has been started to develop an optical communications payload for a NASA relay spacecraft that will orbit Mars. This launch is planned for 2009. It will enable the return of mission data to Earth at much higher rates than is possible with RF communications techniques of the same payload size. Innovative photon-counting receiver and modulation techniques will be employed on the Earth to maximize the data rate. The laboratory will also build a demonstration receiver based on an array of small telescopes whose individual detection outputs are combined to maximize detection probability and remove false detections caused by background light.

Advanced Electronics Technology

The laboratory continues to develop and demonstrate advanced electronics technologies associated with its sensing and communications research. Compact, short-pulse laser transmitters and 32 x 32 arrays of Geiger-mode avalanche photodiodes (APDs) with per-pixel timing circuits were transitioned into two airborne laser imaging, ranging, and detection systems. Flight demonstrations to identify objects under trees have been successfully concluded at the 532-nm wavelength, along with airborne topographic mapping at the 780-nm wavelength. Both of these applications exploited silicon APDs. For future systems, development of APD arrays that are sensitive at longer wavelengths will enable the use of more efficient pulsed laser illuminators. Recently APDs in compound semiconductors have been shown to operate in the Geiger mode at 1.06- and 1.55-micron wavelengths.

Previously a new diode-laser structure, the slab-coupled optical-waveguide laser (SCOWL), was demonstrated to simultaneously provide a higher emitted optical power level and a circular, single-mode diffraction-limited beam. Now, by exploiting a wavelength-beam-combining configuration in which the lasers are placed in a grating-controlled external cavity, a linear array of 90 SCOWLs has produced 15W power. This is the highest brightness laser-diode demonstration to date, with the output in a nearly ideal beam over a waveband of 8.5 nm centered near 980-nm wavelength.

The laboratory maintains a strong research portfolio, exploring the performance limits of advanced silicon-based devices for potential use in high-frequency electronic systems. This past year, a 22-nm gate length pMOSFET exhibited a cutoff frequency of 280 GHz, which is the highest published report for a silicon MOS transistor. These deeply scaled MOSFETs incorporate platinum-silicide Schottky-barrier source and drains for inherently low series resistance and high drive current and are promising candidates for high-speed analog/RF applications.

Summary

The demand for the laboratory's support among its sponsors is very strong. The programs cover a broad spectrum of activities and there is a healthy diversity in the sources of sponsorship. Our prototyping efforts have had a significant growth over the past few years, indicative of the laboratory's critical role in technology development, technology maturation, and transfer of knowledge to industry. Recruitment of highly qualified personnel continues to be very productive, and the investment across the laboratory to facilitate collaborative efforts is increasingly contributing to productivity and technical vitality.

Preparations for a new five-year contract between MIT and the government have included many favorable assessments of Lincoln Laboratory's performance and the stewardship of MIT. At this time, everything is on track for the signing of a new five-year contract agreement early in calendar year 2005.

David L. Briggs
Director

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

Appendix A

MIT Lincoln Laboratory Organizational Structure