Lincoln Laboratory, located at Hanscom Air Force Base.
Message from the Director

MIT Lincoln Laboratory celebrated its 50th Anniversary in 2002. Since its creation in 1951, the Laboratory has maintained an impressive record of technical innovation in critical national security technology areas such as satellite communications, air and missile defense, space surveillance, optics, laser systems, sensor systems and technology, advanced electronics, network security, and, more recently, homeland protection.

The Laboratory’s reputation has been built on the strength and quality of its technical staff, and we allocate a major portion of time and resources to recruiting, staff development, and continued education. Formal graduate studies are strongly encouraged as one means of ongoing learning. For staff members interested in pursuing technical graduate degrees at the master’s and doctoral levels, the Laboratory offers the opportunity to apply for admission to the Lincoln Scholars Program, which enables the pursuit of advanced degrees on a full-time basis.

This brochure provides an overview of our objectives, fields of research, and primary mission areas, as well as information about the Laboratory work environment. Also included are profiles of some of our technical staff. I encourage you to read about their experiences and accomplishments and to note their comments on the opportunities and benefits of working at MIT Lincoln Laboratory.

We are committed to sustaining our legacy of technical excellence, innovation, and integrity. If you are interested in conducting next-generation applied research and development in a dynamic, exciting environment, I encourage you to consider applying for employment at MIT Lincoln Laboratory.

Dr. Eric D. Evans
MIT Lincoln Laboratory — Technology in support of national security

MIT Lincoln Laboratory offers scientists and engineers the opportunity to work on challenging problems critical to national security. A Department of Defense federally funded research and development center (FFRDC), Lincoln Laboratory has a focused commitment to research and development, with an emphasis on building prototypes and demonstrating operational systems under live test conditions that meet real-world requirements.

Three areas constitute the core of the work performed at Lincoln Laboratory: sensors, information extraction (signal processing and embedded computing), and communications, all supported by a broad research base in advanced electronics.

The research and development activities at the Laboratory are encompassed under seven primary mission areas:

- Space Control
- Air and Missile Defense Technology
- Communications and Information Technology
- Intelligence, Surveillance, and Reconnaissance Systems and Technology
- Advanced Electronics Technology
- Homeland Protection
- Tactical Systems

Lincoln Laboratory also undertakes government-sponsored, nondefense projects such as the development of systems for the Federal Aviation Administration to improve air traffic control and air safety, and systems the National Oceanic and Atmospheric Administration uses in weather surveillance.
**Objectives**

The Laboratory’s principal technical objective is the development of components and systems for use in experiments, engineering measurements, and tests under field operating conditions. State-of-the-art facilities—such as the Laboratory’s RF System Test Facility, its Microelectronics Laboratory, and its airborne test bed facility—support this work.

The Laboratory takes projects from the initial concept stage, through simulation and analysis, to design and prototyping, and finally to field demonstration. This full-cycle approach engenders collaborations among technical staff from diverse disciplines.

Approximately 1,500 technical staff members work on research, building prototypes, and field demonstrations. These technical staff come from a broad range of scientific and engineering fields. Two-thirds of the professional staff hold advanced degrees, and 60% of those degrees are at the doctoral level.

Emphasis is also on the dissemination of information to the government, academia, and industry. Lincoln Laboratory technical staff have been responsible for over 500 patents and have published 112 books. Staff members produce approximately 160 journal articles, conference speeches, and technical reports annually. Over the years, more than 90 companies have been “spun off” from projects that initiated at the Laboratory.

Since its establishment in 1951, Lincoln Laboratory has developed innovative technology to meet national security needs. In 2001, the Laboratory received the Secretary of Defense Medal for Outstanding Public Service in recognition of a half-century of distinguished technical innovation and scientific discoveries.

As the challenges confronting the nation have changed, the Laboratory has evolved to find solutions to new problems. Yet, the mission has remained unchanged—to apply technology in service to national security.
Current Work

Over the last 58 years, Lincoln Laboratory has expanded its research areas to meet emerging national security needs. The following list illustrates the broad range of fields in which the Laboratory is currently working.

Sensors and Information Extraction
- Adaptive array processing
- Advanced RF technology
- Advanced radar development
- Advanced visible and sensor concepts
- Analog signal processing
- Bioagent identifiers
- Biological trigger sensors
- Critical Measurements and Countermeasures
- Deep-space surveillance
- Electro-optical and infrared sensing
- Environmental monitoring
- Ground-based sensors
- High performance embedded computing
- Integrated sensing and decision support
- Laser radar applications
- Multisensor integration
- Open systems architecture
- Optical sensors
- Phased-array radar
- Polymorphous computing architectures
- Satellite tracking
- Space-object identification
- Surface moving-target indicators
- Superresolution technology
- Three-dimensional LADAR algorithms
- Ultrasensitive chemical-agent detectors
- Ultrawideband technology

Communications
- Airborne communications networks
- Communications signal processing architectures
- Heterogeneous IP networks
- Laser communications
- Mobile networking protocols
- Net-centric communications
- Network security
- Optical communications
- Satellite communications on the move
- Speech and language processing
- Transformational satellite communications

Advanced Electronics
- Advanced solid-state devices
- Advanced imaging
- Electro-optical devices
- High-performance photodetector arrays
- Immersion lithography
- Microelectronics
- Microelectromechanical switches
- Nanometer-scale fabrication
- Quantum electronics
- Semiconductor lasers
- Superconductive electronics
- Three-dimensional integrated circuits
- Yb laser technology
Field Sites

Lincoln Laboratory is engaged in field work at sites in the continental U.S. and the Pacific region.

The Experimental Test Site (ETS) is an electro-optical test facility located on the grounds of the White Sands Missile Range in Socorro, New Mexico. Situated next to the U.S. Air Force’s Ground-Based Electro-Optical Deep Space Surveillance field site, the ETS is operated by the Laboratory for the Air Force. The principal mission of the ETS is the development, evaluation, and transfer of advanced electro-optical space surveillance technologies. Approximately six Laboratory staff are assigned to the ETS.

Lincoln Laboratory serves as the scientific advisor to the Reagan Test Site at the U.S. Army Kwajalein Atoll installation located about 2,500 miles WSW of Hawaii. Twenty staff members work at this site, serving two- to three-year tours of duty. The site’s radars and optical and telemetry sensors support ballistic missile defense testing and space surveillance. The Laboratory also supports upgrades to the command-and-control infrastructure of the site.

At the Pacific Missile Range Facility (PMRF) on the Hawaiian island of Kauai, Lincoln Laboratory personnel provide technical advice and analysis support. The Laboratory has had significant input into PMRF sensor designs and implementations.
Christine Wang

SB, Materials Science and Engineering, Massachusetts Institute of Technology
MS, Metallurgy, Massachusetts Institute of Technology
PhD, Electronic Materials, Massachusetts Institute of Technology

Dr. Wang has been developing new materials processes to produce advanced semiconductor crystals used for short-wave infrared diode lasers, mid-wave infrared quantum cascade lasers, detectors, and photovoltaics. Her goal is to understand the physics of these devices and to tailor the materials properties so she can produce state-of-the-art devices based on arsenides, phosphides, and antimonides. These devices have applications in power generation, mid-infrared countermeasures, molecular gas sensing, laser radar systems, optical communications, and biological and chemical sensing.

“The nature of the projects we work on,” says Chris, “requires an interdisciplinary group of scientists and engineers. It’s a great opportunity to work with staff that are highly regarded because of their intelligence, motivation, and dedication. When you’re a part of this kind of team, some great accomplishments are inevitable.”

“Being able to present and publish one’s research reinforces the value of the work we do here. There’s a lot of personal satisfaction in knowing that one’s peers in the scientific community highly respect our work.”
Space Control

Lincoln Laboratory detects, tracks, and identifies man-made satellites; accomplishes satellite mission and payload assessment; and investigates technology to improve monitoring of the space environment, including space weather and atmospheric and ionospheric effects. The technology focuses are the application of new components and algorithms to enable sensors with greatly enhanced capabilities and the development of network-centric processing systems for the nation’s Space Surveillance Network.

Space Surveillance

Among the highly capable space surveillance systems operated by Lincoln Laboratory is the Lincoln Space Surveillance Complex (LLSC) in Westford, Massachusetts. The complex, which constitutes the foundation of the Laboratory’s ground-based radar space surveillance programs, is composed of three high-power radars: Haystack Imaging Radar operating at X-band, Haystack Auxiliary Radar operating at Ku-band, and Millstone Hill Tracking Radar operating at L-band. The Millstone Hill Tracking Radar, along with the Space-Based Visible sensor designed and integrated at Lincoln Laboratory, provides space situational awareness data to support more than 50 new launches each year. A multistatic radar test bed consisting of the Haystack and Haystack Auxiliary illumination radars, three fixed received sites, and one transportable receive site recently began operations. The test bed was used to demonstrate wideband bistatic tracking and interferometric three-dimensional inverse synthetic aperture radar imaging of satellites in low Earth orbits. The Haystack Ultrawideband Satellite Imaging Radar (HUSIR) under development for installation at the LSSC will improve the ground-based inverse synthetic aperture radar resolution by an order of magnitude, thus enabling a significant increase in collection activities.
Lincoln Laboratory is pursuing initiatives in the space control area. These include the next generation of sensor systems and downstream processing/information-extraction systems such as the following:

- A small-aperture, space-based, space surveillance system to provide wide-area search of the geosynchronous belt
- Net-centric machine-aided decision-support algorithms to allow the operators in the JSpOC to react to short-timescale, emerging threats to space assets

Progress in providing space situational awareness and astronomical synoptic search applications is enabled through the Space Surveillance Telescope (SST), a sensor that combines innovative curved charge-coupled device imager technology developed at Lincoln Laboratory with a very wide field-of-view, large-aperture telescope. The SST will possess advanced ground-based optical system capability for detection and tracking of objects in space.

Another asset to the space control mission is the Ground-based Electro-Optical Deep Space Surveillance (GEODSS) system in Socorro, New Mexico. The GEODSS system supports wide-ranging, electro-optical surveillance. A spin-off NASA program, Lincoln Near-Earth Asteroid Research, is using the GEODSS system to discover near-Earth asteroids; more than 50% of the known asteroids in our solar system have been discovered through this program.

**Net-Centric Capabilities**

The Laboratory’s vehicle for bringing space situational awareness into the net-centric realm is the Extended Space Sensor Architecture (ESSA). This network-centric test bed leverages proven technologies, including sensor sidecars, web-based technologies such as XML (eXtensible Markup Language) or WSDL (Web Services Description Language), and net-centric services. Under ESSA, space surveillance sensors will be made net-centric, and information exploitation engines will be developed to feed off databases and sensors. As a result, operators will have access to a broad variety of real-time information that will enable a responsive decision-making process. The first ESSA deliveries into the Joint Space Operations Center (JSpOC) have already provided the capability for real-time images from the Laboratory’s Haystack Auxiliary sensor to JSpOC operators.

**Outlook**

Lincoln Laboratory is pursuing initiatives in the space control area. These include the next generation of sensor systems and downstream processing/information-extraction systems such as the following:

- A small-aperture, space-based, space surveillance system to provide wide-area search of the geosynchronous belt
- Net-centric machine-aided decision-support algorithms to allow the operators in the JSpOC to react to short-timescale, emerging threats to space assets
Christ Richmond

BS, Mathematics, Bowie State University
BS, Electrical Engineering, University of Maryland, College Park
EE, SM, and PhD, Electrical Engineering, Massachusetts Institute of Technology

“We, in essence, develop the ‘smarts’ behind several of the nation’s technologically advanced sensor systems.”

Dr. Richmond’s work consists of theoretical and algorithm development in the general area of detection and parameter estimation theory applied to diverse types of adaptive sensor array systems often deployed in complex (high multipath) environments dominated by limiting interference. His work has been applied to airborne radar, sonar underwater acoustic systems, and multiple-input multiple-output (MIMO) communication systems, and includes signal processing development in space-time adaptive processing (STAP), adaptive beamforming, spectral analysis, performance bounds (Bayesian, non-Bayesian, and non-asymptotic) on parameter estimation (e.g., maximum-likelihood estimation of signal range, Doppler, and/or angle) and receiver operation characteristics (probability of detection vs. false-alarm rate).
Lincoln Laboratory works with government, industry, and other laboratories to develop integrated systems for defense against ballistic missiles, cruise missiles, and air vehicles in tactical, strategic, and homeland defense applications. An important component of this program is the focused evaluation of the survivability of U.S. air vehicles against air defense systems. Air and missile defense technology activities include investigation of system architectures, development of advanced sensor and decision-support technologies, development of flight-test hardware, extensive field measurements and data analysis, and verification and assessment of deployed system capabilities. Emphasis is placed on the rapid prototyping of sensor and system concepts and algorithms, and the transfer of the resulting technologies to government contractors responsible for the development of operational systems.

Advanced Concepts

The Laboratory is exploring advanced algorithms and architectures for target detection in noise and clutter, multitarget and multisensor fusion, and sensor resource management. The Laboratory is analyzing radar and optical sensor data to identify phenomenologies that can be exploited to improve target identification and subsequent engagement. Programs are also emerging to develop new radar open systems architectures for phased-array radars. The Laboratory is creating the next-generation software and hardware architecture for missile defense radars. This work includes developing new digital beamsteering and beamforming subcomponents and testing existing phased-array hardware.
Ranges and Test Beds

Lincoln Laboratory serves as the scientific adviser to the Reagan Test Site (RTS) on the Kwajalein Atoll in the Marshall Islands, providing technical leadership for the suite of radar, optical, and telemetry instrumentation, as well as the mission control and communications functions. At the Pacific Missile Range Facility, located on Kauai, Hawaii, the Laboratory provides technical support, including the definition and evaluation of range instrumentation and infrastructure needs of current and future range customers.

The Laboratory’s efforts have made dramatic improvements to the commonality of the radars at both sites through development of the Radar Open Systems Architecture (ROSA). At RTS, the Laboratory’s efforts have been fundamental to the upgrade of the Range Operations Coordination Center (ROCC). The RTS Distributed Operations project, building on the open architectures of ROSA and ROCC, is focused on developing a system to demonstrate remote viewing of RTS sensor data and remote control of RTS sensors.

A significant milestone in this project has been real-time demonstrations involving the control of RTS radars from the Laboratory’s site in Lexington, Massachusetts. This capability will allow operators to view and execute missions from widely dispersed operational sites.

Ballistic Missile Defense System (BMDS): Systems and Architectures

The Laboratory is assessing architectural options for the evolving BMDS, with emphasis on sensor measurements and target discrimination to mitigate a growing spectrum of countermeasures. Evaluation of counter-countermeasure performance of both near-term BMDS configurations and long-term options is ongoing. This function draws upon the Lexington Decision Support Center for threat representation, algorithm and decision logic testing, and BMDS simulation. The Laboratory’s mission planning, execution, and data analysis resources are used to focus hardware-in-the-loop testing and risk-reduction flight tests as well as end-to-end system flight tests.

Seeker and Interceptor Technology

The Laboratory continues to improve its capability to develop and test advanced missile seekers for the BMDS. Programs are focused on developing advanced digital focal plane arrays and coherent range-Doppler LADAR systems as well as the testing of LADAR seekers against advanced countermeasures.

Outlook

The Laboratory’s future directions for air and missile defense technology programs include the following:

- Characterizing the capabilities and limitations of deployed components of the Ballistic Missile Defense System and helping develop, refine, and verify tactics, techniques, and procedures to optimize the system’s performance
- Participating in the analysis, development, testing, and implementation of further capabilities for the BMDS—particularly, system-wide tracking and discrimination, system-level testing, and advanced counter-countermeasure techniques
- Defining architectures for the defense of the U.S. homeland against asymmetric attacks by cruise missiles or short-range ballistic missiles launched from ships off the U.S. coast
Since joining the Advanced Lasercom Systems and Operations Group at Lincoln Laboratory, Dr. Nowak has helped manage the group’s work on designing and testing laser terminals to support high-bandwidth networking among aircraft and satellites. Specific initiatives in the group involve the design and construction of multi-Gb/s optical transceivers; a subsystem for conducting pointing, acquisition, and tracking among terminals; and optical assemblies to emulate free-space laser propagation over geosynchronous orbit distances. The group also develops high-speed electronic interfaces to provide forward-error correction and bit interleaving to mitigate the impairments of laser communication through the lower atmosphere. The group’s efforts have contributed to accelerating the progress of national laser communication programs.

“There are great opportunities to help solve interesting problems—not only conceptually, but also by building the hardware and fielding systems that contribute to our nation’s security.”

George Nowak

BS, Mathematics and Electrical Engineering, United States Military Academy, West Point

MEA, Construction Management, George Washington University

MS, Electrical Engineering, Rensselaer Polytechnic Institute

PhD, Electrical Engineering, University of Michigan, Ann Arbor
Communications and Information Technology

Lincoln Laboratory is working with the Department of Defense, government agencies, and industry to deliver the Global Information Grid vision. Efforts in this area include transport, network and data services, information assurance, and applications. Emphasis is on extending a robust networking capability to deployed space, air, land, and marine platforms. Lincoln Laboratory also identifies, develops, and field tests new architectures, component technologies, and algorithms for the following:

- Satellite communications
- Aircraft and vehicle radios
- Network nodes
- Wideband sensor networks
- Network operations centers
- Speech processing systems

Advanced Apertures
In collaboration with industry, the Laboratory is working to realize low-profile, low-cost, multiband antennas for use on wide-body and fighter aircraft. The antenna apertures are designed to support the data rates necessary for network operations while having minimal impact on platform performance.

Networking Capability
Lincoln Laboratory conducted a series of operator-on-the-loop evaluations of airborne network nodes and architectures, teaming with industry to compare the impact of different network architectures on mission outcomes. Testing was done with pilots using real-time,
full-motion flight simulators. In another initiative, flight-test campaigns were carried out to assess the effectiveness of airborne intelligence, surveillance, and reconnaissance; airborne networking; and network middleware concepts.

Information Assurance

In response to the problem of ensuring the security of information traveling over networks, the Laboratory has developed the Lincoln Adaptable Real-time Information Assurance Test bed (LARIAT). By providing a high-fidelity emulation of large-scale networks with up to 1000s of hosts and 10,000s of users, LARIAT is employed in evaluating the effectiveness of information security tools and techniques. LARIAT has already been deployed to several government facilities. The Laboratory has also demonstrated a system that assesses the security of enterprise networks and automatically recommends changes to eliminate vulnerabilities.

Transformational Satellite Communications (TSAT)

Working with industry, the Laboratory used the TSAT test and evaluation infrastructure it developed to validate standards for RF signaling waveforms, network protocols, and free-space optical signaling. The Laboratory also used the test environment to perform a series of independent tests at Laboratory and contractor facilities to support the TSAT Technical Readiness Assessment.

Communications on the Move

The Laboratory continues to be involved in solutions for communications on the move. Apertures and algorithms developed at the Laboratory have enabled protected communications on the move. A programmable digital core consisting of field programmable gate arrays, digital signal processors, and a general-purpose computer has been developed; the digital core is capable of processing a wide spectrum of communications waveforms, ranging from line-of-sight radios to protected satellite communications.

Outlook

Future initiatives will be focused on the following:

- Service-oriented architecture techniques for sharing data and enabling dynamic work flows among diverse network-connected sensors, processors, and decision-support tools
- Additional functionalities to the transformational communications test beds
- High-sensitivity optical receivers that enable small, high-performance lasercom terminals for air, ground, and space applications
- Algorithms for speech, language processing, and information operations techniques for use in counterterror network analysis and intent recognition
Pedro Torres-Carrasquillo

BS, Electrical Engineering, University of Puerto Rico, Mayagüez
MS, Electrical Engineering, The Ohio State University
PhD, Electrical Engineering, Michigan State University

“Satisfaction at Lincoln Laboratory comes from working on problems on the edge of technology with resources available to pursue innovative ideas.”

Dr. Torres-Carrasquillo’s work is in speech processing. His research is focused in two areas: speech analysis for downstream processing and information extraction from speech. In speech analysis for downstream processing, he has worked on speaker diarization, which is the marking of speech into areas of similar speaker content. In information extraction from speech, he has worked in both speaker and language identification: speaker identification involves determining the identity of a speaker based on previously known voice examples, and language identification involves identifying the language spoken on a given voice message.
Lincoln Laboratory conducts research and development in advanced sensing concepts, networked sensor architectures, and decision systems. Work encompasses airborne and space-borne radar, high-resolution laser radar, passive geolocation systems, and undersea acoustic surveillance. Intelligence, surveillance, and reconnaissance (ISR) work relies upon the Laboratory’s expertise in the enabling technologies of high-performance embedded computing, advanced RF and optical sensing, and adaptive signal processing.

Advanced Signal Processing

The Laboratory continues to advance the state of the art in radar signal processing. A new airborne radar concept for wide-area detection of slowly moving targets has been prototyped. This concept is enabled by processing that adaptively combines synthetic aperture radar images on each transmit/receive channel of a sparse aperture to suppress ground clutter. Research in nonlinear signal processing has proven useful to mitigate the impact of nonlinear distortions from RF components, thereby increasing the achievable dynamic range of wideband communication and radar receivers.

In undersea surveillance, the Laboratory has made significant contributions in two areas. New adaptive beamforming algorithms for submarine hydrophone arrays have improved detection performance in noisy littoral environments. The Laboratory has pioneered an automatic classification architecture and sets of feature detectors that enable operators to effectively manage a large search space.

Intelligence, Surveillance, and Reconnaissance Systems and Technology
Outlook

Future focuses for the ISR systems and technology mission include the following:

- Developing imager, processing algorithm, and processor technologies to improve the capabilities of persistent electro-optical systems
- Miniaturizing receivers and sensor payloads for small unmanned aerial vehicles to provide a capability for enhanced RF sensing applications
- Developing a net-centric ISR architecture test bed that will include space and airborne ISR assets, sensor exploitation, and decision support capabilities
- Developing new high performance computing architectures to enable the processing for graph-based exploitation algorithms to run on small form factors
William S. Song

BS, MS, and PhD, Electrical Engineering, Massachusetts Institute of Technology

“Lincoln Laboratory offers ample opportunities to pursue new and interesting research ideas. I also appreciate the chance to collaborate with great expert colleagues in many fields.”

Since his arrival at Lincoln Laboratory in 1990, Dr. Song has been working on high-performance sensor and VLSI signal processor technologies for adaptive sensor array applications. He has developed numerous advanced signal processing algorithms, architectures, real-time embedded processors, and sensor array systems. Recently, he has been working on a nonlinear equalization processor, mixed-signal system on chip, high-throughput low-power VLSI signal processors, and highly digitized wideband sensor arrays. His research has been applied to programs developing a miniaturized digital receiver and a space-based radar onboard processor.
Research and development in Advanced Electronics Technology involves the invention of new device concepts, the practical realization of those devices, and their integration into subsystems for system demonstrations. Lincoln Laboratory’s broad electronics expertise includes 3-D integration and silicon microphotonicics, optical lithography, thermoelectric devices, superconductive electronics, and diode and solid-state lasers.

The Laboratory is developing high-performance photodetector arrays in which each pixel is sensitive to a single photon. Improved silicon Geiger-mode avalanche photodiodes were used to enable the Defense Advanced Research Projects Agency’s Jigsaw ladar sensor to achieve high range resolution. The 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 Lincoln 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.
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 5–110 GHz. The Laboratory’s technology transfer program with a commercial MEMS foundry is laying the groundwork for a domestic source of high-performance, high-reliability RF MEM components suitable for integration into DoD systems.

**Microelectronics Laboratory**

The Laboratory’s Microelectronics Laboratory, a state-of-the-art semiconductor research and fabrication facility, provides significant support to its electronics work. Current activities include a variety of projects:

- Fabrication of flight-quality gigapixel charge-coupled device imager focal planes
- Photon-counting avalanche photodiode arrays
- Radio frequency and optical microelectromechanical systems, niobium-based superconducting circuits
- A fully depleted silicon-on-insulator CMOS circuit prototyping capability

In addition, the Microelectronics Laboratory supports advanced packaging with a precision multichip module technology and an advanced three-dimensional circuit stacking technology.

**Outlook**

Future advanced electronics research will be directed toward the following:

- Imaging and RF technologies for Department of Defense and civilian remote-sensing applications
- Laser technologies supporting communication and targeting systems
- Cryogenics 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

A unique orthogonal transfer array has been developed for synoptic space surveys in the Air Force’s Panoramic Survey Telescope and Rapid Response System (Pan-STARRS). Sixteen orthogonal transfer arrays have been assembled into a $4 \times 4$ abutted format, and field tests are being initiated at the telescope being built for Pan-STARRS.
Dr. Suntharalingam leads projects to design and develop scientific image sensors for ground- and space-based telescopes. These next-generation technologies are built in Lincoln Laboratory’s Microelectronics Laboratory (a class-10 semiconductor fabrication facility) and other on-site labs. Devices, circuits, and image sensors developed at the Laboratory are used as innovative prototypes for future satellites, telescopes, and communications systems. “In the Solid State Division,” says Vyshi, “we have projects that address fundamental research topics as well as larger-scale programs to innovate designs to meet specific system requirements. A key reason I came to Lincoln was the ability to publish at peer-reviewed technical conferences while working on much broader programs than could be tackled in an academic environment.”
Lincoln Laboratory is developing technology and systems for addressing homeland security and defense problems:

- Preventing terrorist attacks within the U.S.
- Reducing the vulnerability of the U.S. to terrorism
- Minimizing the damage and assisting in recovery from terrorist attacks

**Homeland Protection**

The Laboratory’s efforts in airspace surveillance include the development of the Enhanced Regional Situation Awareness (ERSA) system of radar and electro-optical sensors, track fusion logic, and evidence accrual tools. ERSA is deployed to the National Capital Region to provide enhanced air defense surveillance capabilities.

The Laboratory is working on cyber-security technology for critical infrastructure protection as well as collision-avoidance technology that will enable the use of unmanned aerial vehicles for homeland protection.
To support unmanned aerial vehicle integration into civil airspace, the Laboratory developed an architecture for collision-avoidance system modeling and secured data feeds from approximately 200 radar sensors across the United States to build statistics on the collision threat environment.

Lincoln Laboratory has emphasized the development of biological sensors that signal the presence of an aerosol threat in sufficient time to recognize it and take protective measures. The Biological Agent Warning Sensor (BAWS) has been transitioned to industry, and a prototype upgrade to BAWS has significantly improved its false-alarm characteristics.

In other initiatives addressing chemical and biological threats, the Laboratory has undertaken architecture studies for the defense of civilians and facilities against potential biological attacks; demonstrated initial operation of a test bed designed to test potential chemical and biological sensors and protection methods; and completed homeland security system architectures for biological defense against a variety of bioagents in both indoor and outdoor domestic settings.

**Outlook**

Future work in homeland protection will focus on the following:

- Biological and chemical defense architecture studies, system development, and system evaluations
- The application of persistent surveillance technology to U.S. border surveillance and maritime domain awareness
- The development of additional capabilities for the ERSA system
- The application of airspace models to evaluate airborne collision-avoidance systems developed for the Department of Homeland Security’s unmanned aerial vehicle operations

The Laboratory’s homeland protection initiatives also include development of a suite of air-vehicle identification algorithms to support homeland air defense applications. This effort leverages 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 is substantial intellectual property usable in future domestic air defense applications.
Dr. Seeley’s work focuses on remote chemical sensing using infrared spectroscopy. Remote chemical sensing has applications in chemical threat detection, environmental monitoring, and weather sensing. Dr. Seeley has contributed to the development of a linear variable filter-based passive imaging spectrometer and a bistatic single-pixel infrared sensor with cooperative source that monitors the environment outside the Laboratory’s auditorium. She has also participated in the development of a Fourier transform infrared–based hyperspectral imager using digital focal-plane array technology. Currently, she supports NASA in the development of the Advanced Baseline Imager, a passive multispectral imager that is part of the instrument suite planned for the future weather-sensing satellite, GOES-R (for Geostationary Operational Environmental Satellite).
Lincoln Laboratory works with the Department of Defense (DoD) to improve the acquisition and employment of tactical air and counterterrorism systems. By helping the U.S. military understand the operational utility and limitations of advanced technologies, the Laboratory enables the DoD to make better decisions about the acquisition and deployment of systems. Activities in the Tactical Systems mission focus on a combination of

- Systems analysis to assess technology impacts in operationally relevant scenarios
- Rapid development and instrumentation of prototype U.S. and threat systems
- Detailed, realistic instrumented testing

The mission’s efforts are characterized by a very tight coupling between the Laboratory’s work and the needs of DoD sponsors and systems users. This coupling ensures that the analyses performed and the systems developed are relevant and beneficial.
Prototyping

A key component of the Laboratory’s prototyping activities is the rapid development of systems incorporating advanced technologies. These prototype systems may be potential advanced U.S. systems designed for transition to operational use or potential advanced threat systems to be used for testing U.S. systems and for assessing the future threat to DoD operations. The prototypes, selected and designed based on systems analysis that highlights critical technologies, are typically heavily instrumented and tested in ways that allow their performance and limitations to be assessed via data analysis. Incorporated into these prototypes are technologies from across Lincoln Laboratory, including advanced receivers, specially designed antenna systems, and open system architectures.

Field and Flight Testing

Lincoln Laboratory operates a number of unique test assets to assist with the development of tactical systems. The Airborne Seeker Test Bed and the Advanced Countermeasure Test System are business jet aircraft with sophisticated sensors, electronics, and data recording devices used in testing with advanced U.S. Air Force systems. These airborne test beds allow collection of truth and phenomenological data to help researchers understand the performance of operational and developmental systems. The continual modernization of these systems is guided by the data collected through flight testing. Other airborne platforms, such as newer unmanned aerial vehicle systems, are also used for test and development purposes. In addition, a wide range of ground test assets that the Laboratory has developed or adapted support field-test activities.

Outlook

Future directions for tactical systems technology programs include the following:

- Helping the U.S. Air Force develop advanced electronic attack and electronic protection systems for its aircraft, and demonstrating the need for and robustness of those systems
- Rapidly developing prototypes of counterterrorism/counterinsurgency systems to help the DoD operate within the technology development timeline of the threat
- Employing modeling and testing techniques to develop an improved understanding of the potential threats to U.S. aircraft

Systems Analysis

A hallmark of Tactical Systems’ work is the systems analysis done to incorporate test results and to assess critical technologies. Such analyses are used to highlight the operational utility of the technologies in question, thereby enabling senior DoD decision makers to make better-informed determinations about Laboratory-proposed prototypes as well as about large acquisition efforts from the contractor community. The analyses are also used to help users understand how to employ and train with advanced systems that have already been acquired.
Mr. Skelly has been developing novel data processing and computer vision algorithms with a concentration on state-of-the-art 3-D imaging laser radar sensors developed at Lincoln Laboratory. With the support of the Lincoln Scholars Program, he has earned a master’s degree from Boston University; his thesis focused on finding correspondence between 3-D surface maps. This work can be applied to merging datasets from different sensors or sensors with unknown location and orientation; recognizing landscapes, cities, or objects; and tracking multiple targets of unknown shape.

“The Lincoln Scholars Program gave me a chance to fulfill my educational goals and focus my attention on problems of interest to both myself and the Laboratory in research areas such as laser radar sensors.”
Jonquil Swann

BS, Computer Engineering, Rensselaer Polytechnic Institute

MS, Electrical Engineering with a concentration in Software Engineering, Rensselaer Polytechnic Institute

“My career at the Laboratory has mainly been about opportunities—opportunities to work in the Pacific, to take classes at Harvard, to attend conferences, and to use a cutting-edge architecture like Eclipse Rich Client Platform. Such opportunities are a constant here—and available to everyone.”

Ms. Swann’s background in software engineering has led to her involvement in many projects at the Laboratory. These projects have focused on ballistic missile defense but have afforded her diverse software opportunities, from creating mission-planning tools using MATLAB to developing a visualization application using the Eclipse Rich Client Platform (RCP). This RCP application is used to visualize mission activities at the Reagan Test Site and is built using the Eclipse framework, which provides a common graphical user interface infrastructure in addition to system features. The latest challenge is to expand this tool to cover mission activities across multiple locations.
Air Traffic Control

For over 30 years, Lincoln Laboratory has supported the Federal Aviation Administration (FAA) in the development of new technology for air traffic control. Work historically focused on aircraft surveillance and weather sensing, collision avoidance, and air/ground datalink communications. In recent years, the emphasis in aviation research has shifted to the development of advanced integrated weather systems, decision-support technologies to improve aviation safety, open systems architecture applied to air surveillance sensors, information security, and collaborative approaches to air traffic management.

Integrated Weather Systems

The Laboratory has developed sensors, automated forecasting systems, and decision-support tools to reduce the impact of adverse weather on commercial aviation. The Laboratory is developing algorithms from Doppler weather radar, automated surface observing stations, geostationary environmental satellites, and numerical weather-prediction models to forecast thunderstorm activity; the goal is to improve the prediction of convective initiation from very short tactical time scales (30 minutes to two hours) out to eight hours in order to enable strategic planning. The Route Availability Planning Tool (RAPT) represents the Laboratory’s first work in the area of coupling weather forecast information into decision-support tools used by air traffic management. RAPT has been demonstrated in New York and future applications are expected for other major U.S. airports.

The Laboratory-developed Corridor Integrated Weather System (CIWS) is in use at eight en route centers and six major terminal control areas in the northeast U.S., as well as in the Air Traffic Control System Command Center. The CIWS integrates data from national weather radars with thunderstorm-forecasting technology. Ongoing software engineering work to restructure the CIWS prototype has enabled coverage of the continental U.S.
Air Traffic Management

Lincoln Laboratory developed the original beacon-based, air-to-air coordination logic for the Traffic Alert and Collision Avoidance System (TCAS). The International Civil Aviation Organization now mandates TCAS for all large aircraft worldwide. The Laboratory continues to monitor and analyze TCAS performance in order to enhance the system’s threat logic and to develop a TCAS monitoring system that will cover the entire National Airspace System.

The Laboratory continues to support the evaluation of and enhancements to the Runway Status Lights, a system of surveillance-driven status lights that provide flight crews and vehicle operators with indicators warning that runways are occupied or in use by high-speed aircraft.

Outlook

Future initiatives in aviation research will focus on the following:

- A modern communications architecture for weather information, including network-enabled weather forecasting for the National Airspace System
- Broader coupling of weather information with air traffic management
- An integrated, net-centric surveillance architecture to support air traffic control and homeland defense missions
- Prototype decision-support tools that incorporate weather forecast uncertainty as well as estimates of weather forecast uncertainty

The Integrated Terminal Weather System, with the one-hour Terminal Convective Weather Forecast, was developed and tested by Lincoln Laboratory at airports in New York, Dallas, Orlando, and Memphis. It is now an FAA operational system built by Raytheon Company and deployed at most large airports. This project illustrates the complete cycle of the Laboratory’s work on an FAA system from concept, research, and prototype to technology transfer, contractor development, production, and certified operations.
At Lincoln Laboratory, technical innovation means more than putting ideas on paper or simulating them numerically. It means building ideas into hardware and software that can be field tested or used operationally. The Laboratory’s development efforts range from building small, light satellite payloads that meet the requirements of a NASA mission to building some of the world’s largest ground-based telescopes and radar antennas with revolutionary capabilities and accuracies. Technical staff work on every aspect of system development, from conceiving fundamental new technologies embedded in a system, to creating innovative designs, to overseeing fabrication and assembly, and finally to testing and operating the system under realistic conditions. This approach enables Lincoln Laboratory to rapidly develop new system concepts into successful prototypes.

In support of its prototyping efforts, Lincoln Laboratory maintains broad capabilities in design, fabrication, assembly, and integration, particularly for mechanical, optical, and control systems. Extensive analysis and test capabilities in the mechanical, electromechanical, controls, and aerospace engineering fields are available. The Laboratory has also developed equipment and facilities for environmental testing relevant to space, aircraft, and ballistic missile payloads.

Installing an upgrade to an advanced laser system
Hardware Capabilities

For more than 50 years, Lincoln Laboratory has demonstrated the ability to create and deliver complex systems that include both hardware and software. For the Department of Defense and NASA, the Laboratory has built one-of-a-kind, fully space-qualified payloads in timelines as short as two to three years from initial concept to launch. These payloads incorporated advanced technologies, such as passive visible or infrared sensing and laser communication, into both short-duration technology demonstrators or long-duration capabilities such as the Space-Based Visible sensor that operated on the Midcourse Space Experiment Satellite for over 12 years. The Laboratory develops a wide variety of communications and sensor payloads for testing on a variety of airborne test beds; these payloads are fully qualified for the flight environment. The Engineering division has supported the Laboratory’s long-standing development of ground-based radar and optical systems for the Department of Defense by providing mount and gimbal system selection and design, pointing and stabilization control system design, real-time embedded software, telescope optical design, and radar antenna structural analysis and design.

Outlook

Future focuses for engineering include the following:

- Building and employing complex hardware prototypes that incorporate advanced technologies; envisioned projects include developing smaller spacecraft payloads for laser communication and passive optical sensing, and rapid prototyping for aircraft payloads
- Enhancing capabilities in mechanical design and analysis, fabrication, electronics assembly, integration, and environmental testing

Current Hardware Development

The Laboratory is engaged in a number of major hardware development efforts. For the Haystack Ultrawideband Satellite Imaging Radar project to upgrade a large ground-based radar for space surveillance, the Laboratory performed advanced structural and thermal design, analysis, and validation testing for the antenna that requires the 35 m diameter primary reflector to have an effective surface error of better than 100 µm rms. An enhancement to an advanced laser system required the packaging of hundreds of individual optical elements, along with cryogenic dewars and water-cooled lasers, in a very compact form to meet airborne integration and safety needs. For NASA’s Lunar Laser Communications Demonstration, the Laboratory will design, fabricate, and operate both the ground- and space-based components of an optical communication system that will demonstrate high-rate optical communications from lunar orbit.
MIT Lincoln Laboratory is committed to the professional development of its staff. The Laboratory encourages staff to pursue advanced degrees and continuing education. The tuition assistance program provides support for qualified courses of study at MIT or other schools in the Boston area. The Lincoln Scholars Program, for which technical staff are eligible to apply, enables the pursuit of advanced degrees on a full-time basis. Our in-house education program offers courses in technical subjects such as electro-optics, classes in software applications, one-day technical seminars, and workshops in leadership and business skills.

Lincoln Laboratory has developed a new educational initiative, the Leadership Development Program for Contracting, to prepare candidates for careers in contract administration. Through a combination of online coursework and varying work assignments within the Laboratory, participants earn a university-level certificate in Government Procurement and Contracts Management while advancing from an entry-level position to a subcontracts administrator supporting the Laboratory’s research programs.

Support for professional activities is strong. The Laboratory encourages staff to publish in technical journals, attend conferences, and participate in activities of their professional societies. In addition, interdisciplinary projects and the diversity of work allow individuals opportunities to follow new interests and grow professionally.

The Laboratory’s onsite library supports the educational activities of the staff with a comprehensive collection of books, technical papers, journals, and multimedia; an extensive archive of Laboratory publications; and multiple online resources.
Collaborations with MIT Campus

Lincoln Laboratory’s affiliation with MIT promotes research collaborations, knowledge exchange, and staff development. The MIT Office of the Provost and the Laboratory Director’s Office strongly support the Campus Interaction Committee, whose principal focus is joint research and policy seminars. Emerging areas of joint research include photon integration, superconducting photon counters, and advanced signal processing.

As a large interdisciplinary system laboratory, Lincoln Laboratory is able to offer a breadth of expertise to campus researchers, both faculty and students. The Laboratory’s ability to architect and build sensors that enable significant campus research is well established. One unique collaboration between the Laboratory and the MIT campus is the Integrated Photonics Initiative, a multiyear effort that has MIT PhD candidates working with Laboratory researchers on integrated photonics devices and subsystems for potential insertion into advanced communications systems.

The Laboratory’s Advanced Concepts Committee is another vehicle for establishing technical interactions. The committee supports the development of new systems and promotes improvements to current practices. Many of the Advanced Concepts Committee’s funded projects are cross-disciplinary, and projects involving collaborations with campus are encouraged.
MIT Lincoln Laboratory is committed to reaching out to the local community through educational and civic programs. To help enhance K–12 science education, the Laboratory initiated two outreach programs. Through the Science on Saturday program, over 2500 local students, their parents, and teachers have enjoyed demonstrations presented at the Laboratory by technical staff members. Topics for these demonstrations have ranged from chemistry to cryogenics to lasers and optics. Under the Science Seminar Series, technical staff have visited local K–12 schools, giving presentations on science and engineering to more than 6000 students. For local-area high-school students, the Laboratory conducts educational tours during which students learn about current research in microelectronics, communications on the move, chemical/biological-agent detection, and air traffic control technologies.

Lincoln Laboratory has joined a group of companies in sponsoring the Leadership Initiatives for Teaching and Technology (LIFT?) program. The program addresses the decline in the number of people properly equipped with the education necessary for a technology-driven economy by providing middle- and high-school teachers with summer employment “externships” that will strengthen their backgrounds in applied math, science, and technology.

The Lincoln Laboratory Community Outreach (LLCO) Committee promotes community service in partnership with the MIT Public Service Center. Proceeds from events such as a 5K “fun run” and a used-book drive/sale are divided between the United Way and the MIT Community Service Fund, which offers grants to charities in Boston and Cambridge. The LLCO has also fostered participation in food-donation drives, used-clothing drives for local shelters, a benefit bike tour, and a drive to send goods to U.S. soldiers stationed overseas.
Benefits and Work-Life Balance

MIT Lincoln Laboratory’s commitment to its employees is supported by a comprehensive benefits package, a competitive vacation policy, and the availability of services to make a work-life balance possible.

The benefits package includes health and life insurance; retirement and 401(k) savings plans; and tuition assistance and educational loan plans. A relocation assistance program is also available.

Lincoln Laboratory staff are eligible to join the Fitness Center housed in the Lincoln Laboratory Health and Wellness Center. The Fitness Center offers both cardio and weight-training equipment, a beach volleyball court, half-court basketball, and a horseshoe pit. In addition, the Center conducts a variety of fitness classes.

The Lincoln Laboratory Health and Wellness Center houses a medical facility operated by the MIT Medical Department and staffed by internists, nurse practitioners, and social-work professionals. While the facility is a primary-care center for members of the MIT Health Plan, all Laboratory employees are eligible for brief primary-care visits.

Lincoln Laboratory employees can take advantage of the child-care center located on the campus of nearby Minuteman Regional High School. This center, one of MIT’s Technology Children’s Centers, provides developmentally based infant, toddler, and preschool programs for children from 8 weeks to 5–6 years old. Dr. Vyshi Suntharalingam noted, “The on-site day care/preschool has been a safe and stimulating environment for my children, and also had the unexpected benefit of introducing me to a lot of other Lincoln parents.”
Lincoln Laboratory’s location in historic Lexington, Massachusetts, just 14 miles from Boston, means the educational, cultural, and recreational offerings of the city are easily accessible.

The Boston area has many fine universities, including MIT, Harvard, Boston University, and Northeastern University, as well as smaller colleges such as the Berklee School of Music, Massachusetts College of Art, and Simmons College.

The art scene in Boston includes the Museum of Fine Arts, the new Institute for Contemporary Art, and many small galleries. Music lovers have choices ranging from the classical offerings of the Boston Symphony Orchestra to more contemporary performances at venues throughout the city. Boston’s theaters present the Boston Ballet’s performances, Broadway shows, and touring stage productions.

Sports fans can attend games of the New England Patriots, Boston Red Sox, Celtics, and Bruins. Boston is within easy driving distance to beaches, mountains, and lakes, affording outdoor enthusiasts with opportunities to enjoy four seasons of recreational activities.
Aerial view of Downtown Boston, across the Charles River from Massachusetts Institute of Technology
MIT Lincoln Laboratory’s fundamental mission is to apply science and advanced technology to critical problems of national security. To assure excellence in the fulfillment of this mission, the Laboratory is committed to fostering an environment that embraces and leverages diversity of thought, culture, and experience.

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