1951–2011
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TECHNOLOGY IN SUPPORT OF NATIONAL SECURITY

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CELEBRATING SIXTY YEARS

1951–2011

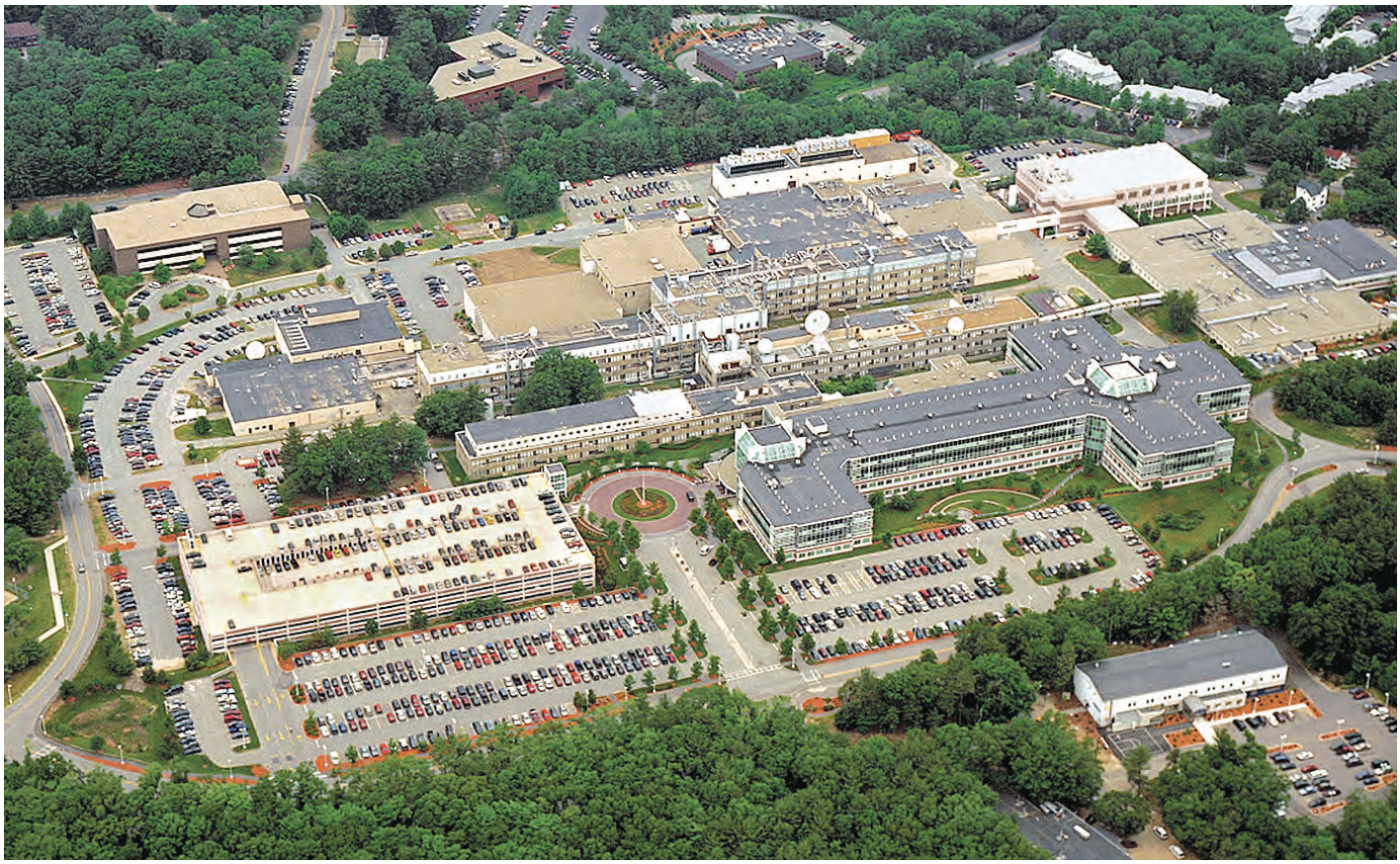
MIT LINCOLN LABORATORY

ANNUAL REPORT

Technology in Support of National Security

2011

Massachusetts Institute of Technology



MIT Lincoln Laboratory

MIT LINCOLN LABORATORY 2011

MISSION

Technology in Support of National Security

MIT Lincoln Laboratory employs some of the nation's best technical talent to support system and technology development for national security needs. Principal core competencies are sensors, information extraction (signal processing and embedded computing), communications, integrated sensing, and decision support. Nearly all of the Lincoln Laboratory efforts are housed at its campus on Hanscom Air Force Base in Massachusetts.

MIT Lincoln Laboratory is designated a Department of Defense (DoD) Federally Funded Research and Development Center (FFRDC) and a DoD Research and Development Laboratory. The 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. Projects undertaken by Lincoln Laboratory focus on the development and prototyping of new technologies and capabilities to meet government needs that cannot be met as effectively by the government's existing in-house or contractor resources. Program activities extend from fundamental investigations through design and field testing of prototype systems using new technologies. A strong emphasis is placed on the transition of systems and technology to the private sector. Lincoln Laboratory has been in existence for 60 years. On its 25th and 50th anniversaries, the Laboratory received the Secretary of Defense Medal for Outstanding Public Service in recognition of its distinguished technical innovation and scientific discoveries.

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Leadership

Massachusetts Institute of Technology

Dr. Susan Hockfield
President

Dr. Claude R. Canizares (standing left)
Vice President for Research and Associate Provost

Dr. L. Rafael Reif (standing right)
Provost

MIT Lincoln Laboratory

Dr. Eric D. Evans
Director

Dr. Marc D. Bernstein (standing left)
Associate Director

Mr. Anthony P. Sharon (standing right)
Assistant Director—Operations

Organizational Changes

In 2011, organizational changes in the Communication Systems and Cyber Security Division and the Homeland Protection and Air Traffic Control Division address the strategic goal of strengthening and evolving mission areas to meet emerging national security needs.

Communication Systems and Cyber Security Division

A new group, the Cyber System Assessments Group, was formed to meet the expanding need for research into and solutions to the increasingly important issue of cyber security. The group's mission is to provide the government with independent assessments of cyber systems and capabilities. The group is developing cutting-edge technical capabilities for understanding, testing, assessing, and analyzing cyber technologies. In addition, the group is using a red-team approach to identify vulnerabilities in U.S. systems and to characterize the cyber capabilities of adversaries. The group's work complements that of the Cyber Systems and Technology Group.

Homeland Protection and Air Traffic Control

The Bioengineering Systems and Technologies Group was established to expand the Laboratory's core competencies in chemical and biological agent detection and identification to better support Department of Defense initiatives in bioengineering. The group's focuses will include bioinformatics, synthetic biology, biometrics/forensics, and biomedical systems for health diagnosis and treatment.

New Leadership

Charles W. Maxson

Department Head, Information Services

Charles W. Maxson joined Lincoln Laboratory in June 2011 to lead the Information Services Department. His background in information technology (IT) includes work on infrastructure, security, and enterprise applications, including positions at research and higher education organizations. He has prime responsibility for the Laboratory's central IT services, as well as management of its internal information-based services. Major directions for the department in the coming year include increased collaboration and alignment with the Laboratory's research divisions; continued Business Process Improvement; and improved infrastructure, tools, and services for information stewardship and retrieval, research collaboration, and enhanced security.

Letter from the Director

This year, MIT Lincoln Laboratory observed its 60th anniversary, and we have been reflecting on the legacy of our technology development in support of national security. To ensure that this proud heritage continues, the Laboratory is also looking toward the future, strengthening its work in core areas, such as air defense, communications, space surveillance, and advanced electronics, while expanding important new research areas, such as cyber security, homeland protection, and intelligence, surveillance, and reconnaissance (ISR) systems. The recent upgrade to our Microelectronics Laboratory and a significant investment in modern fabrication and assembly equipment ensure that we will have the laboratory equipment and facilities for future needs.

Some major long-term programs marked significant milestones over the past year. In February 2011, the Space Surveillance Telescope (SST) achieved first light. SST is a multiyear project to develop a telescope capable of wide-field-of-view detection of small objects at very long ranges. A program to enable remote range operations for the Reagan Test Site (RTS) also made substantial progress. New network, processor, and display hardware allowed tests at the Kwajalein Atoll to be conducted remotely from Huntsville, Alabama, and Lexington, Massachusetts.

Other recent technological achievements included the following:

- The design and fabrication of new RF microwave hardware doubled the bandwidth of the Millimeter Wave (MMW) radar at the Reagan Test Site. The new hardware was installed and tested, and the system became operational with 4 GHz bandwidth in March 2011. The expanded bandwidth doubles the radar image resolution, making MMW the highest-resolution satellite-imaging radar in the world.

- A successful evaluation of the Collaborative Storm Prediction for Aviation (CoSPA) system was conducted at congested air traffic control facilities. CoSPA's high-resolution convective weather forecasts support ground-delay and rerouting decisions. CoSPA is expected to become a key component of the Federal Aviation Administration's next-generation decision support environment.

- The Imaging System for Immersive Surveillance (ISIS) was operationally tested at Boston Logan International Airport. ISIS is a video system that provides 360° surveillance at centimeter-class resolution from a single vantage point. The system was developed to support protection of the nation's critical infrastructure.

- The Laboratory demonstrated an RF link that uses advanced multiple-input, multiple-output (MIMO) techniques and adaptive space-time coding to support data rates from 1 Mb/s up to 1.9 Gb/s. This system's capabilities enable efficient data transfer from ground-based ISR network systems.

- Laboratory researchers developed a suite of tools to enable automatic analysis of malicious software. These tools demonstrated effective analysis of thousands of malicious software samples.

- A new tactical radio test range was demonstrated over-the-air. The range will provide comprehensive instrumentation and evaluation of emerging tactical communications systems and waveforms on ground and airborne mobile radio platforms.

- A novel robot-mounted sensor system for use by military engineering teams for route-clearance applications was developed and deployed.

The Technology Office fostered increased collaboration with MIT campus and other university researchers to assure that the Laboratory remains aware of emerging technologies in the academic community. New research investments were made in the areas of autonomous systems, quantum information sciences, cyber security, and biomedical technology.

The Laboratory's educational outreach programs for K–12 students grew in both reach and depth. The Robotics Outreach at Lincoln Laboratory (ROLL) added eight teams and three new activities to its program. Two teams mentored by ROLL volunteers won awards at the World Championship in St. Louis, Missouri, sponsored by the For Inspiration and Recognition of Science and Technology (FIRST) organization. Our involvement with the MIT Office of Engineering Outreach Programs expanded, and an ongoing partnership with the John D. O'Bryant School of Mathematics and Science in Roxbury, Massachusetts, was strengthened with the addition of a robotics mentorship and an after-school program.

As this annual report shows, 2011 was an exciting and productive year. Many technical programs reached significant milestones, and our newer mission areas of homeland protection and cyber security are yielding new solutions to critical problems in national security. We encourage you to review the 2011 Annual Report to learn more about our current technical efforts, as well as our educational outreach activities. We look forward to the future as we continue to focus on technical excellence, innovation, and integrity.

Sincerely,

Eric D. Evans
Director

Lincoln Laboratory Strategic Directions

The strategic directions below are based on a Director's Office and senior management update of the Laboratory's strategic plan and a review of national-level studies, such as the National Defense Strategy, the Quadrennial Defense Review, and recent Defense Science Board recommendations.

- Identify new mission areas, based on current and emerging national security needs
- Strengthen and evolve the current Laboratory mission areas
- Strengthen the core technology programs
- Increase MIT campus/Lincoln Laboratory collaboration
- Strengthen technology transfer to acquisition and user communities
- Increase outside connectivity and communications
- Improve Laboratory diversity and inclusion
- Expand community outreach and education
- Continue improving Laboratory administration and infrastructure

TECHNOLOGY INVESTMENTS 7

THIS PAGE: The Microelectronics Laboratory underwent upgrades in 2011 that significantly increase its capabilities. See page 13.

Technology Investment Overview

Lincoln Laboratory responds to evolving challenges to national security by investing in technology development for its traditional mission areas, for emerging research thrusts, and for early-stage basic and applied research.

The Technology Office is responsible for developing and directing strategic research at the Laboratory through focused investments in existing and emerging mission areas. Members of the office interact regularly with the Assistant Secretary of Defense for Research and Engineering (ASD[R&E]), Defense Advanced Research Projects Agency, Department of Homeland Security, and other government agencies to maintain awareness of the critical problems that threaten national security and to grow strategic technical relationships. The office also collaborates with and supports university researchers and, in doing so, aids in the translation of new technologies from laboratory scale to end-user needs. The internal research and development (R&D) investment portfolio is managed through a number of mechanisms, including competitive solicitations, open calls for proposals in specific technical areas, focused infrastructure investments, and activities designed to promote innovative thinking and creative problem solving.

R&D Investment Portfolio

Internal R&D funding at Lincoln Laboratory primarily derives from congressional appropriations administered by ASD(R&E). The Technology Office's investment strategy is focused on ensuring that the Laboratory is appropriately coupled to emerging technology developments, that the Laboratory remains relevant to emerging problems of national security, and that adequate resources and technical infrastructure exist so that the Laboratory can advance into appropriate new technology and mission areas. The internal R&D investment portfolio reflects this strategy, supporting investments in technical infrastructure, basic and applied research, research thrusts that address emerging national security challenges, and technology development for current Laboratory mission areas.

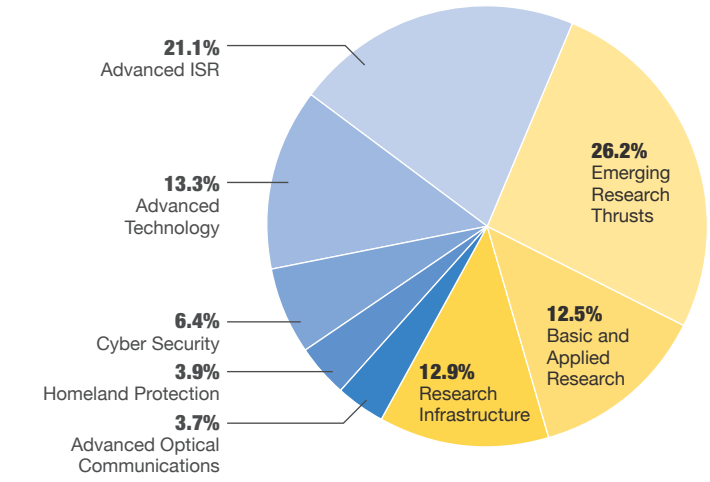
LEADERSHIP

Dr. Bernadette Johnson

Dr. William Herzog

Dr. Andy Vidan

Internal R&D Funding



2011 Highlights

Projects Within Mission Areas

In 2011, technology investments supported projects within five mission areas, enabling both new technology development and advanced system demonstrations.

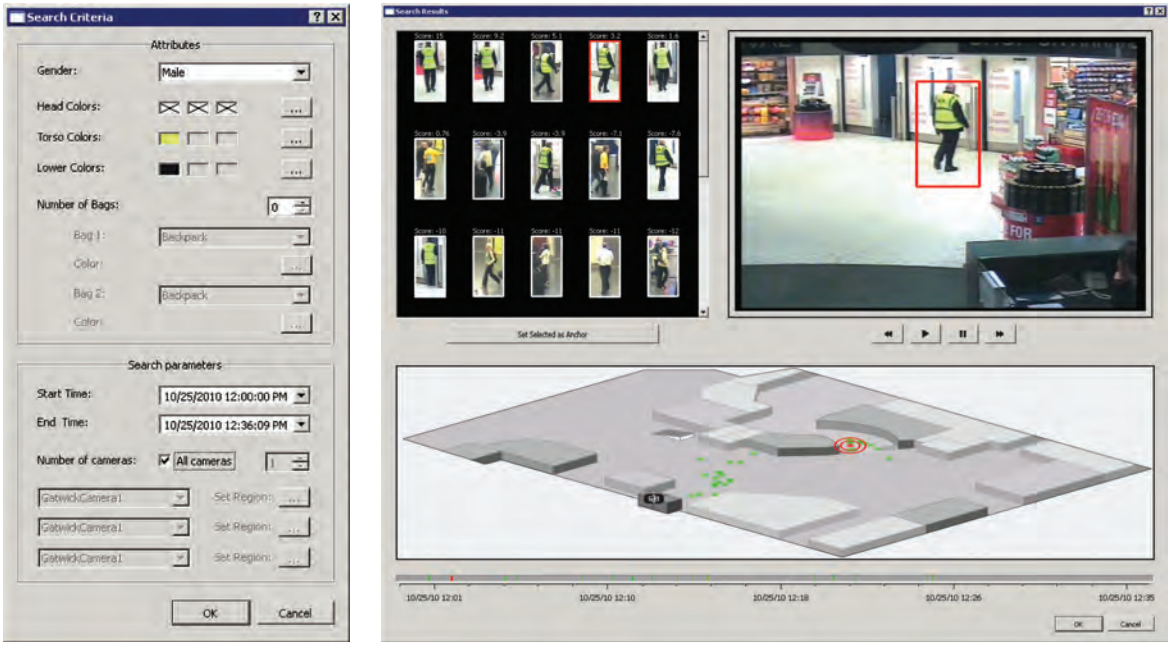
- Advancements in net-centric operations enable users to respond to unanticipated missions. New technologies include a framework to allow users to construct, share, and execute applications without programming; an architecture and prototype implementation for federating resource-brokering agents; a preference language for automated machine processing of user preferences in resource allocation and tasking; and an architecture and prototype implementation of a tactical-edge service-oriented architecture.

- A network mission-assessment tool kit that assists security analysts with automatically mapping missions to underlying cyber elements is permitting analysts to more easily identify assets, processes, and dataflows that are critical for each mission. Preliminary experiments using machine-learning-based classifiers on operational web proxy logs demonstrated automatic classification of the underlying mission with greater than 80% accuracy.

- For application to advanced intelligence, surveillance, and reconnaissance (ISR) systems, miniaturized signals-intelligence systems were demonstrated on small, hand-launched unmanned aerial vehicles (UAV). One system, utilizing a custom receiver based on the Laboratory's high-performance receiver-on-chip technology, allowed a spur-free dynamic range in excess of 90 dB. The front end was coupled with a custom, low-power, field-programmable gate array (FPGA)–based digital back end, resulting in a system weighing 2.7 oz, consuming approximately 15 W, and fitting in a 5" × 3" × 1.5" enclosure.

- Several novel video analytics techniques were demonstrated for real-time monitoring or forensic analysis of surveillance video content. New techniques employ computer vision and machine-learning concepts to automate searches of video content. One capability allows an operator to search for persons matching a profile of observable attributes (e.g., clothing color, hair, bag information), while a second capability allows the operator to reconstruct the path of a person moving across a facility.

- The Laboratory hybridized the largest Geiger-mode avalanche photodiode array (GMAPD) produced in-house to date. The new imager has 65,000 pixels with 25 μm pixel pitch. In addition, the Laboratory began producing new GMAPDs by using the advanced 200 mm tools in the Microelectronics Laboratory (see page 13).



Screenshot of the video analytics interactive search tool showing both the search criteria input interface (left) and search results exploration interface (right). In the search results, top matches for the given search criteria are displayed from more than 30 minutes of video from three cameras. Image chips are arranged in order of match score, top to bottom and left to right.

Emerging Research Thrusts

The 2011 investments focused on three areas that exploit the Laboratory's strengths in sensors and communication technologies and that address emerging threats to national security.

Autonomous Systems

Autonomous systems couple unmanned aerial, ground, and maritime vehicles with autonomy algorithms and technologies to enable new system capabilities and amplify the effectiveness of human-robot teams. The Laboratory's autonomous system effort is focused on robust operation of autonomous systems in complex and unpredictable environments; enhanced understanding and trust between humans and robots; and persistent, shared perception and reasoning.

Recent key accomplishments include

- A 22 km demonstration of an autonomous ground vehicle's route re-traversal while the vehicle maintains a standoff distance ahead of a manned follower vehicle. The milestone is part of a project investigating robust navigation through unstructured outdoor terrain.

- The transfer of robot-based, GPS-denied, mapping technology to a mission-focused advanced technology demonstration. In a collaborative effort with MIT campus, the mapping technology is being extended to a body-worn system with video and lidar sensors.

- The application of a cognitive functional model of inner rehearsal to solve a simulated robotic search-and-rescue task. The experiment illustrates an alternative bioinspired approach to autonomy that seeks to effect artificial cognition through emulation of human cognitive and neural processes.

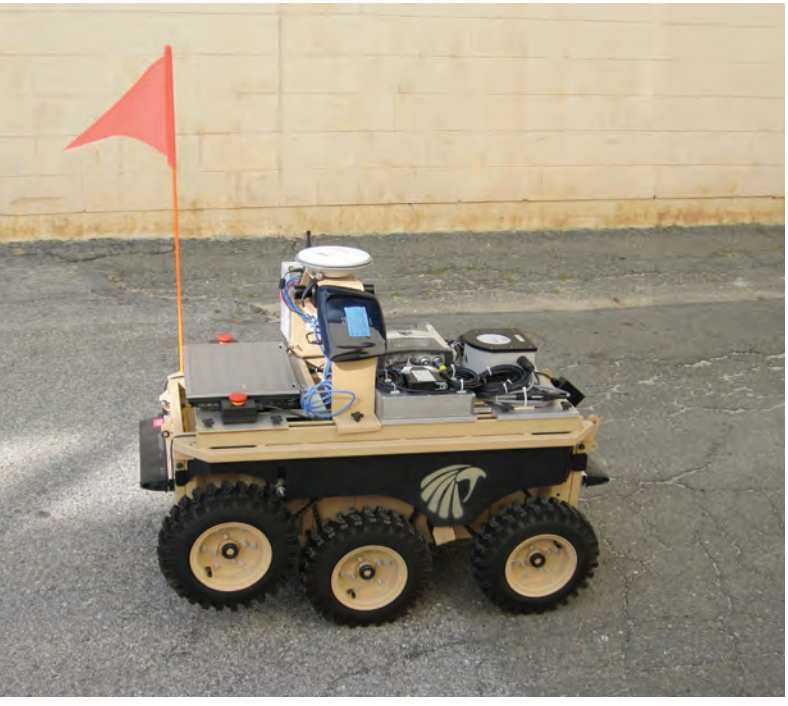
Quantum Information Science

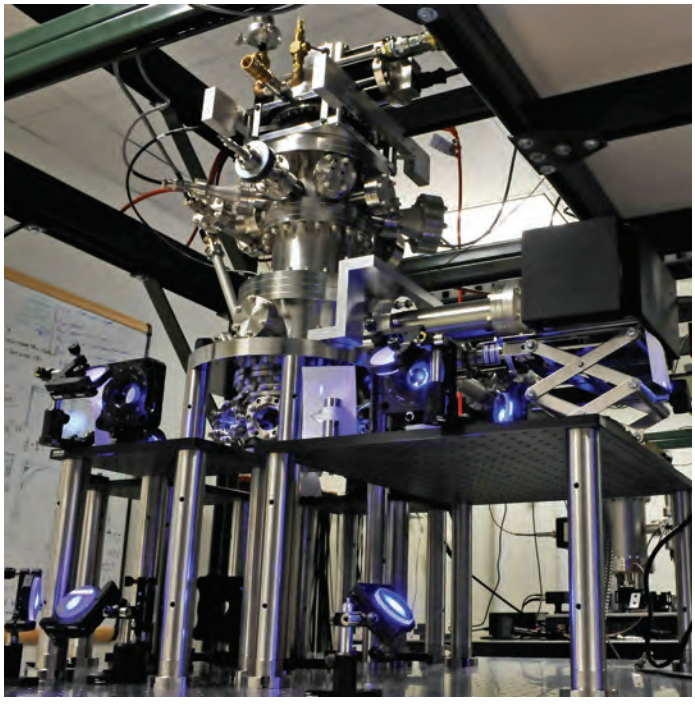
Quantum information science (QIS) addresses the investigation and application of quantum mechanical phenomena for the purposes of sensing, communicating, and processing information in ways that dramatically exceed conventional, classical means. There is significant national interest in the long-term applications of QIS technologies, and the Laboratory continues to make targeted investments in QIS.

The Laboratory continued to distinguish itself in the QIS area with

- Improvements in the design, materials science, fabrication, and testing of superconducting qubits, a leading "artificial atom" technology manufactured in the Microelectronics Laboratory. In a collaboration with MIT campus and NEC Japan, experiments demonstrated advanced microwave methods with

BELOW, FROM LEFT: A Black-I Robotics Landshark ground platform with custom Laboratory hardware and autonomy algorithms serves as an extensible outdoor autonomous ground-vehicle test bed; a new laboratory space housing a magneto-optical trap (MOT) is enabling work in trapped-ion quantum computing. Here, strontium ions are held in a MOT before being individually loaded into a superconducting ion trap that operates at a temperature of 4.5 Kelvin.





up to 1000 control pulses controlling a qubit with a world-record relaxation time of 12 μsec and coherence time of 23 μsec.

- Expanded research portfolio that includes trapped ions, the leading "natural atom" technology, and the successful demonstration of trapped cold atoms in a magneto-optical trap. In the coming year, these atoms will be ionized and loaded into a superconducting surface trap fabricated in the Microelectronics Laboratory.

- New infrastructure investments, including the addition of two cryogen-free dilution refrigerators, a 200 mm molecular beam epitaxial growth chamber, and the renovation of a new laboratory that will serve additional superconducting and ion-trap research and development.

Biomedical Systems and Technologies

Since the 1990s, the Laboratory has had significant impact on national security through existing life-science programs in biometrics and biodefense. The Laboratory is now developing advanced technologies and systems to support the nation's biomedical needs.

Recent milestones were achieved in the research and development of medical detection, control, and analysis at the molecular, cellular, and human system scales:

- Automated microfluidic platforms were developed to sequence DNA, sort adult stem cells without requiring fluorescent labels, and assemble genes and gene networks rapidly.

- Label-free infrared biochemical imaging uses quantum cascade lasers and nanoplasmonic arrays that require no sample modification.

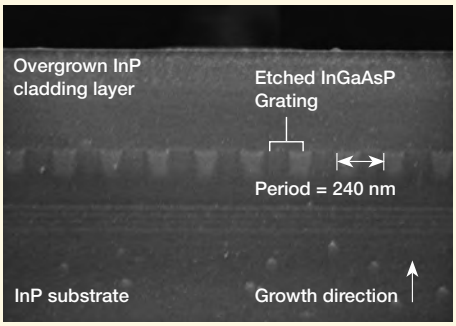
- Technology for predictive monitoring of epileptic seizures outperformed prior capabilities.

- Depression diagnostic tools using physiological sensors and vocal biomarkers exceeded the performance of all other methods described in peer-reviewed literature.

Coherent Optics

INTEGRATED PHOTONICS INITIATIVE

The Integrated Photonics Initiative (IPI) has been developing new devices and subsystems to advance the field of coherent optics, which are of increasing interest for use in applications such as optical communications, laser radar, and microwave photonics. Coherent optics involve the use of the *phase* information of optical signals in addition to their amplitude. William Loh, an MIT graduate student performing his thesis research at Lincoln Laboratory as a member of the IPI, has been working to understand the noise properties of both high-power semiconductor optical amplifiers and narrow-linewidth semiconductor external-cavity lasers.[1,2] These optical sources are potentially enabling components in future integrated transmitters for coherent optical communications and laser radar. During the past year, Loh collaborated with on-campus colleagues to use an interference lithography resource to fabricate gratings that will be used to implement integrated distributed feedback lasers.



Scanning electron microscope image of the lateral cross section of an InGaAsP grating structure that was defined using interference lithography and reactive-ion etching, and then covered with InP by using epitaxial material overgrowth. This grating structure is being integrated with the Laboratory's slab-coupled optical waveguide laser (SCOWL) technology to realize lasers that operate in a single longitudinal mode at a wavelength of 1.55 μm.

The IPI also co-organized a workshop on coherent optics at the 2010 Annual Meeting of the MIT Center for Integrated Photonic Systems. Participants from academia, industry, and government discussed coherent optics challenges and needs within the telecommunications industry and the DoD.

The IPI, a multiyear, Laboratory-funded collaboration with the MIT campus, enhances the research experience for PhD candidates working on integrated photonic devices and subsystems for potential insertion into advanced communication and sensor systems. The program gives students a broader awareness of the DoD's mission and needs, and the Laboratory's specialized facilities and its expertise in applied research add another dimension to students' thesis development.

1 W. Loh, J.J. Plant, J. Klamkin, J.P. Donnelly, F.J. O'Donnell, R.J. Ram, and P.W. Juodawlkis, "Noise figure of Watt-class ultralow-confinement semiconductor optical amplifiers," *IEEE J. Quantum Electron.*, vol. 47, pp. 66–75, 2011.

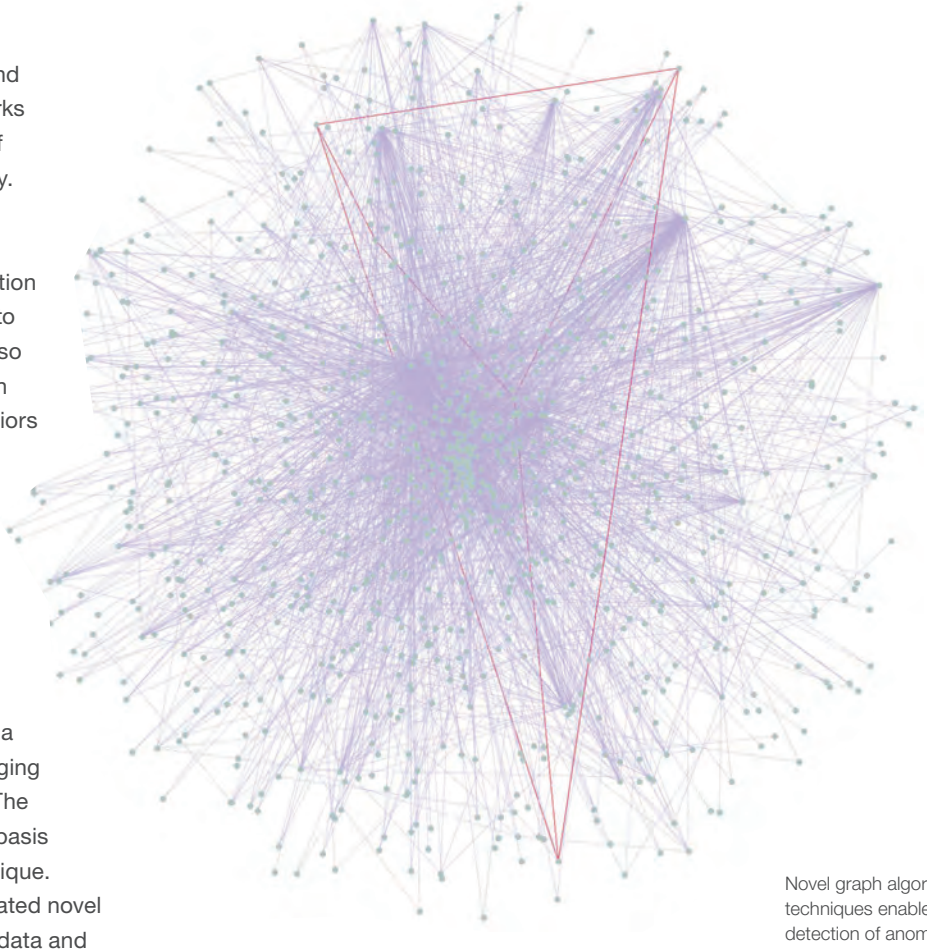
2 W. Loh, F.J. O'Donnell, J.J. Plant, M.A. Brattain, L.J. Missaggia, and P.W. Juodawlkis, "Packaged, high-power, narrow-linewidth slab-coupled optical waveguide external cavity laser (SCOWECL)," *IEEE Photon. Technol. Lett.*, vol. 23, no. 14, pp. 974–976, 2011.

Basic and Applied Research

The 2011 technical investments serve to ensure the rapid transfer of basic and applied research into the defense applications of the Laboratory's sponsors and to strengthen interactions with the Laboratory's academic partners.

Signal Processing for Graphs

The ability to identify interesting groups and group behaviors in a wide range of networks is of growing interest to the Department of Defense (DoD) and intelligence community. Lincoln Laboratory staff and a Harvard University professor are addressing this difficult problem by using statistical detection theory that has traditionally been applied to signals and images. The results achieved so far show that the emerging techniques can detect subtle group formations and behaviors in the presence of noisy and very large background graphs or networks. The Laboratory is looking to apply these techniques to identify threat networks in large social networks or to discover staging sites from vehicle tracking data.



Novel graph algorithm techniques enable detection of anomalous patterns in network traffic.

Imaging into Obscured Areas

Lincoln Laboratory staff and the MIT Media Lab are working to demonstrate laser imaging around corners and into rooms or areas. The Media Lab has developed the theoretical basis for the image reconstruction for this technique. Their reconstruction algorithms demonstrated novel properties and were applied to simulated data and laboratory measurements over short distances. The Laboratory is looking to apply this research to DoD missions because it may offer significant capability in support of urban and Special Forces operations.

Liquid Crystal Thermal Imager

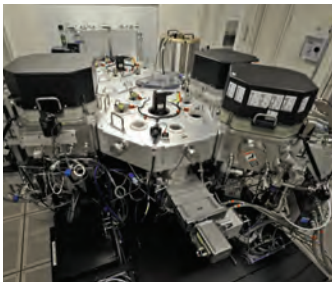
Uncooled thermal detectors have become an indispensible sensor technology in military long-wave infrared (LWIR) imaging applications. The Laboratory is developing a detector that uses sensitive liquid crystals to detect small changes in temperature created by an infrared image. This novel approach combines the liquid crystal detection with readout of the image by using a low-cost, solid-state imager (charge-coupled device or CMOS active pixel sensor). Separating the infrared-to-visible conversion process from the electronic readout enables independent optimization of components for greater performance at lower costs.

Quantum Cascade Lasers

In collaboration with Harvard University, Lincoln Laboratory has been developing advanced quantum cascade laser (QCL) technology for potential use in a variety of DoD applications. In particular, compact arrays of individually addressable (wavelength selectable), watt-class, LWIR semiconductor laser sources would have great utility as rapidly tunable optical sources in spectroscopy-based chemical and biological detection systems. The technical effort at Lincoln Laboratory has focused on the challenging epitaxial growth of high-performance QCL device structures, individual QCL device fabrication, and integration of QCL arrays into wavelength-beam-combined system demonstrations.

Microelectronics Laboratory Upgrade

The MIT Lincoln Laboratory Microelectronics Laboratory is a specially designed, 70,000-square-foot, semiconductor research and advanced prototyping facility with 8100 square feet of class-10 and an additional 10,000 square feet of class-100 cleanroom support space. This state-of-the-art facility supports more than 40 active programs within five divisions at the Laboratory. The Microelectronics Laboratory first came online in fall 1992 as a 100 mm wafer facility and converted to 150 mm wafer processing in 1996. Recent upgrades to the laboratory in 2011 provide the capability for production-class sub-90 nm processing on 200 mm wafers, using 193 nm lithography.



ABOVE, CLOCKWISE FROM TOP: A technician performs bright-light inspection of a 200 mm wafer prior to 3D bonding; chase view of one of the new 200 mm–wafer metal-deposition cluster tools; a 200 mm wafer being loaded into furnace.

Applications

The recapitalization of this laboratory adds tools that significantly increase Lincoln Laboratory's ability to support fabrication of devices that meet current and anticipated Department of Defense (DoD) needs:

- Large-format focal planes for terrestrial and space-based applications
- Denser smart pixel arrays for use in advanced imaging systems
- Higher-performance custom integrated circuits utilizing three-dimensional circuit integration technology
- Flexible processes for heterogeneous integration of nonsilicon materials and devices with silicon-based electronics

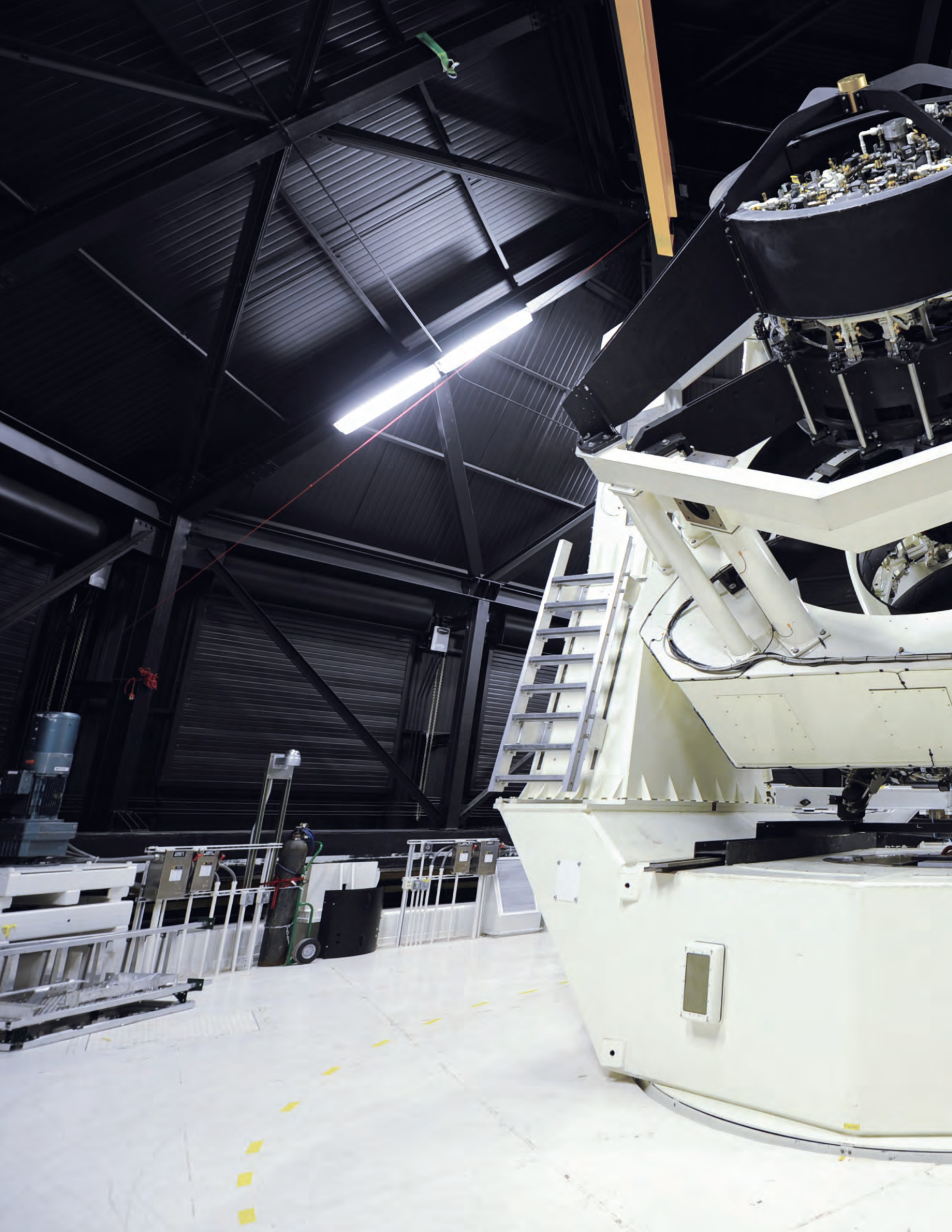
Already the enhanced capabilities of the new tools are being applied to DoD program activities.

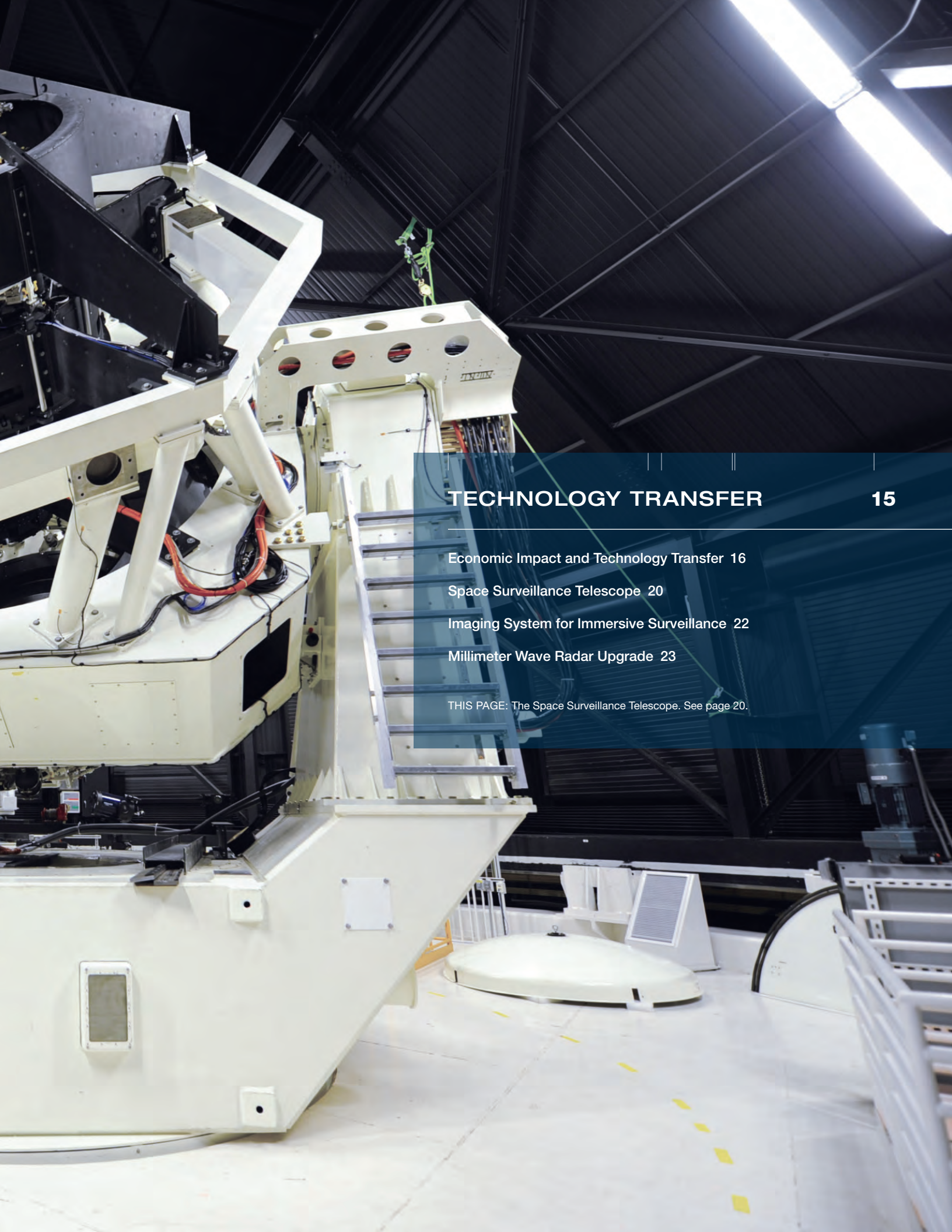
Cutting-Edge Work

The Microelectronics Laboratory has an estimable history of providing cutting-edge technology for DoD systems. Examples of this innovative work include

- High-density, three-dimensional circuit-integration technology
- Fully depleted silicon-on-insulator complementary metal-oxide semiconductor (CMOS) technology for ultra-low-power and extreme-environment electronics
- Curved charge-coupled-device focal-plane arrays for the highly sensitive, wide-field-of-view Space Surveillance Telescope
- Specially designed focal planes for space-based applications such as the Chandra X-ray Observatory
- Microelectromechanical systems (MEMS) for RF, optical, and microfluidic applications

The upgraded laboratory allows Lincoln Laboratory to continue this legacy of researching, developing, and prototyping next-generation advanced electronics technologies.





TECHNOLOGY TRANSFER 15

THIS PAGE: The Space Surveillance Telescope. See page 20.

Economic Impact and Technology Transfer

Lincoln Laboratory's research and development activities strengthen both the nation's technology base and its economy. The continuing development of new capabilities and emerging enabling technologies that are transitioned rapidly to the military services, government agencies, and industry helps ensure not only that advanced technology is available to the U.S. military services and government agencies, but also that U.S. industry is at the forefront of technical innovation.

Technology transfer is accomplished through deliveries of hardware, software, algorithms, or advanced architecture concepts; Small Business Technology Transfer joint research partnerships with local businesses; Cooperative Research and Development Agreements that are privately funded by businesses; and the licensing of MIT patents to companies.

Economic Impact

During fiscal year 2011, the Laboratory issued subcontracts with a value that exceeded $434 million. In 2011, the Laboratory purchased more than $242 million in goods and services from New England companies, with approximately $209 million placed locally in Massachusetts. Small businesses—which supply construction, maintenance, fabrication, and professional technical services in addition to commercial equipment and material—are primary beneficiaries of the Laboratory's outside procurement program. In 2011, 53.4% of subcontracts were awarded to small businesses of all types. The Laboratory's Small Business Office is committed to an aggressive program designed to afford small business concerns the maximum opportunity to compete for purchase orders.

Technology Transfer Activities

Air and Missile Defense Technology

- The U.S. Navy is acquiring the Air and Missile Defense Radar (AMDR) to provide next-generation, integrated air and missile defense capability for future surface combatants. To establish a baseline for the ballistic missile defense mission, the Laboratory developed a prototype architecture for tracking and discriminating targets in all phases of ballistic flight. The AMDR discrimination architecture was delivered to the government, and its component algorithms will be transferred to industry.

- The Laboratory developed the prototype autonomous processing and sensor control computer for the Missile Defense Agency's airborne infrared optical sensing capability for tracking ballistic missile threats. The hardware design and prototype software implementation was then transferred to Raytheon for further development and production.

- The Laboratory has transferred open system architecture technical concepts, algorithms, and standards for use in the U.S. Air Force's next-generation radar systems.

- Iterative Clutter Calibration, an antenna calibration technique for airborne radars, is being transferred to Northrop Grumman, Boeing, and the Commonwealth of Australia (through the U.S. Air Force). The technique uses ground clutter to improve the calibration of an airborne radar antenna to compensate for effects such as airframe interaction and failed antenna elements. Two patents have been filed.

Communication Systems

- The VOCALINC forensic-style speaker comparison tool, which employs state-of-the-art session and channel compensation and speech enhancement, was transferred to the Federal Bureau of Investigation, U.S. Secret Service, and the intelligence community.

- A Laboratory-developed government reference implementation of a high-data-rate waveform for intelligence, surveillance, and reconnaissance (ISR) applications was released to 15 industry participants. The release included VHDL (a hardware description language), software, models, test vectors, and documentation.

- The Large Aperture Ka-band Test Terminal was upgraded to characterize the on-orbit performance of the wideband bypass mode on the Wideband Global Satellite (WGS) Flights 4 and above. The terminal was transferred to the WGS program office and deployed to Camp Parks, California, in preparation for post-launch testing.

Cyber Security

- The Laboratory's patented cyber attack graph modeling and analysis system (called NetSPA for Network Security Planning Architecture) was transferred to FireMon, LLC.

- Context-enriched cyber analysis and display capabilities were developed that provide national-level cyber situational awareness for cyber-threat operations centers. These tools are being used operationally to fuse and visualize cyber threats to put them in the context of organizational mission and tasking priorities.

- Several cyber range network emulation and instrumentation tools were transitioned to government ranges to support testing and experimentation. The Lincoln Adaptable Real-time Information Assurance Testbed (LARIAT) network emulation suite was integrated into the Defense Advanced Research Projects Agency's National Cyber Range program, and the low-observable physical host instrumentation (LO-PHI) tools were transferred to several government organizations.

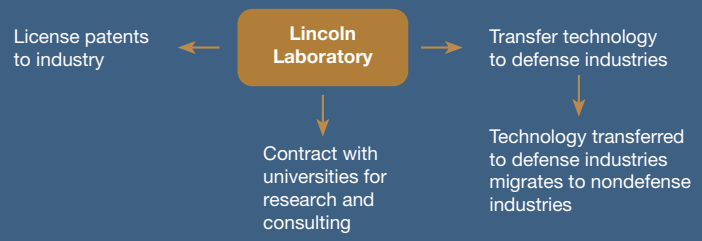
ISR Systems and Technology

- Demonstration flights of the BAE Systems ARGUS-IS sensor were completed in 2011, with integration of this sensor into the U.S. Air Force's Gorgon Stare Increment 2 system expected to be completed in 2012. The ARGUS-IS visible-band sensor system represents technology initially developed and demonstrated in Lincoln Laboratory's Multi-Aperture Sparse Imager Video System (MASIVS) sensor, the first prototype gigapixel-class persistent surveillance system.

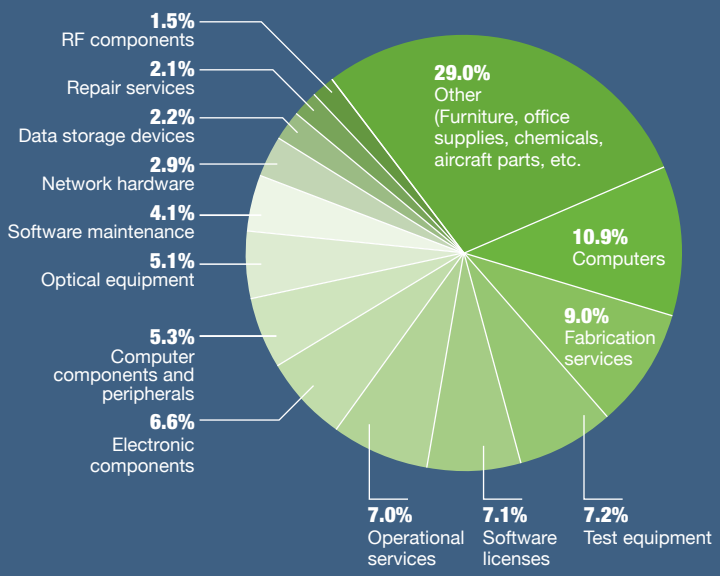
- The Airborne Ladar Imaging Research Testbed (ALIRT) 3D laser radar sensor and onboard processing capability were transferred to the U.S. Air Force.

- Under U.S. Navy sponsorship, sonar signal processing software for enhanced detection, classification, and localization was transferred to Lockheed Martin Corporation for subsequent integration into submarine sonar systems.

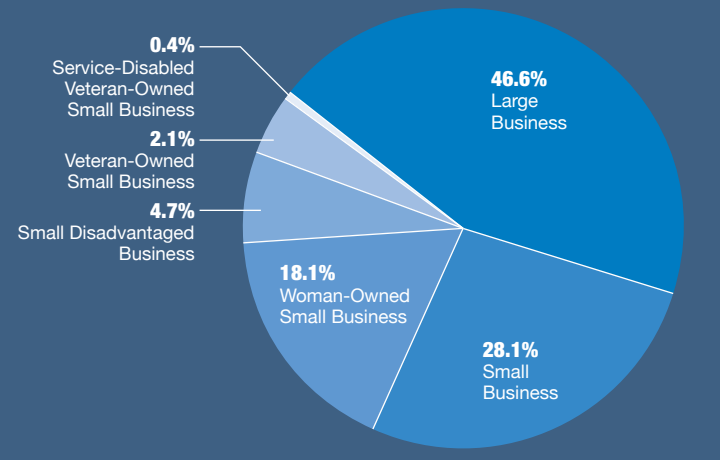
Impact of Lincoln Laboratory's Technology Transfer



(a) Commercial hardware and materials contracted to businesses



(b) Contract awards by category of businesses



- Over the past two years, the Laboratory has sustained a steady transfer of technology to the National Security Agency's Real-Time Regional Gateway (RTRG) program office and its industry partners. This transfer included data-intensive cloud analytics for RTRG data as well as an ingest and analytics pipeline for textual documents.

- The Pyxis software for automated exploitation of ground moving target indication radar data was transitioned to operational users at the National Geospatial-Intelligence Agency and other government agencies.

- Algorithms and a real-time software implementation for processing data from wide-area motion imaging sensors were transferred to Mercury Computer Systems, as part of the U.S. Air Force's Gorgon Stare program.

- The Real-time Enhanced Situational Awareness (RESA) system for providing live tactical intelligence from multiple sources was transitioned to the U.S. Air Force and is in operational use. RESA provides an open systems architecture for real-time distributed processing, exploitation, and dissemination, as well as a framework for real-time ISR data analytics.

Tactical Systems

- As part of a quick-reaction capability ISR program, the Laboratory developed two sensor systems, a UHF radar, and a passive direction-finding sensor that were designed and optimized for counterinsurgency missions. These systems were initially transitioned to operational users in August 2010, and a significant upgrade was transitioned in April 2011.

- The Laboratory rapidly developed and prototyped a tactical, high-capacity data survey system for counterterrorism missions. Two full systems were transitioned to a government partner for operational use in 2011.

- A robot-mounted payload designed for tactical counterinsurgency missions was initially transitioned to industry for limited production in 2010, and subsequent algorithm developments were transitioned to industry and to operationally fielded systems in 2011.

U.S. PATENTS: JULY 2010 TO JUNE 2011

Device for Subtracting or Adding Charge in a Charge-Coupled Device
Michael P. Anthony
U.S. Patent No.: 7,750,962
Date issued: 6 July 2010

GPS-Based Attitude Reference System
George Gorski-Popiel
U.S. Patent No.: 7,760,139
Date issued: 20 July 2010

Method and Apparatus for Simultaneously Measuring a Three-Dimensional Position of a Particle in a Flow
William D. Herzog, Antonio Sanchez-Rubio, Gregory G. Cappiello, Ronald H. Hoffeld, Shane M. Tysk, Vincenzo Daneu, and Thomas H. Jeys
U.S. Patent No.: 7,772,579
Date issued: 10 August 2010

Cube Coordinate Subspaces for Nonlinear Digital Predistortion
Joel I. Goodman, Benjamin A. Miller, and Matthew A. Herman
U.S. Patent No.: 7,808,315
Date issued: 5 October 2010

Method and Apparatus for Measuring a Position of a Particle in a Flow
Thomas H. Jeys, Antonio Sanchez-Rubio, Ronald H. Hoffeld, Jonathan Z. Lin, Nicholas M.F. Judson, George S. Haldeman, and Vincenzo Daneu
U.S. Patent No.: 7,821,636
Date Issued: 26 October 2010

Digital Photon-Counting Geiger-Mode Avalanche Photodiode Solid-State Monolithic Intensity Imaging Focal-Plane with Scalable Readout Circuitry
Alvin Stern, Brian F. Aull, Bernard B. Kosicki, Robert K. Reich, Bradley J. Felton, David C. Shaver, Andrew H. Loomis, and Douglas J. Young
U.S. Patent No.: 7,858,917
Date issued: 28 December 2010

System and Method for Providing a High Frequency Response Silicon Photodetector
Michael W. Geis, Steven J. Spector, Donna M. Lennon, Matthew E. Grein, Robert T. Schulein, Jung U. Yoon, Franz Xaver Kaertner, Fuwan Gan, and Theodore M. Lyszczarz
U.S. Patent No.: 7,880,204
Date issued: 1 February 2011

Time-Multiplexed Optical Waveform Generation
Kevin W. Holman, David G. Kocher, Jae H. Kyung, Leaf A. Jiang, Sumanth Kaushik, and Richard M. Heinrichs
U.S. Patent No.: 7,894,725
Date issued: 22 February 2011

Advanced Technology

- Lincoln Laboratory is being sponsored by the Joint Project Manager–Biological Defense to help transition the Rapid Agent Aerosol Detector (RAAD) to low-rate initial production. The RAAD will replace the current, also Laboratory-developed, detector in the Joint Biological Point Detection System, an integrated suite of biological point detection components designed to provide early warning of bioagents for the Army, Navy, and Air Force.

- The startup company TeraDiode, whose founders include two former Laboratory staff members, is commercializing technology pioneered at Lincoln Laboratory that uses breakthroughs in wavelength beam combining to achieve the brightness and power required for demanding applications such as high-speed cutting and remote welding.

Homeland Protection

- A prototype of the Next-Generation Incident Command System for disaster response has transitioned to operational use by the Southern California first responder community.

- As part of the field-deployable Accelerated Nuclear DNA Equipment program, the Laboratory developed and characterized improved collection and processing procedures for forensic DNA evidence and transferred them to DoD sponsors and users. The program also produced secure DNA profile data analysis and communication software suites that will be transferred to users within the Departments of Defense, Justice, and Homeland Security, as well as industry.

Air Traffic Control

- The Laboratory initiated the transfer of the Route Availability Planning Tool (RAPT) to industry. This transition will lead to the adaptation and deployment of RAPT to the Potomac and Philadelphia areas, planned for late 2012. RAPT is already in use in New York and Chicago to assist air traffic managers in the selection of departure routes that are free from convective weather.

System and Method for Providing Amplitude Spectroscopy of a Multilevel Quantum System
David M. Berns, Mark S. Rudner, Sergio O. Valenzuela, William D. Oliver, Leonid S. Levitov, and Terry P. Orlando
U.S. Patent No.: 7,912,656
Date issued: 22 March 2011

Real-Time Ranging and Angle Measurements Using Radar and Surface Acoustic Wave Transponders
Jason M. LaPenta and Joseph A. Paradiso
U.S. Patent No.: 7,924,160
Date issued: 12 April 2011

System and Method for Detecting Damage, Defect, and Reinforcement in Fiber Reinforced Polymer Bonded Concrete Systems Using Far-Field Radar
Oral Buyukozturk, Tzu-Yang Yu, and Dennis Blejer
U.S. Patent No.: 7,937,229
Date issued: 3 May 2011

Optoelectronic Detection System
James D. Harper, Richard H. Mathews, Bernadette Johnson, Martha S. Petrovick, Ann Rundell, Frances E. Nargi, Timothy Stephens, Linda M. Mendenhall, Mark A. Hollis, Albert M. Young, Todd H. Rider, Eric D. Schwoebel, and Trina R. Vian
U.S. Patent No.: 7,947,509
Date issued: 24 May 2011

Detection of Materials via Nitrogen Oxide
Mordechai Rothschild, Charles M. Wynn, John J. Zayhowski, and Roderick R. Kunz
U.S. Patent No.: 7,955,855
Date issued: 7 June 2011

Generating a Multiple-Prerequisite Attack Graph
Richard P. Lippmann, Kyle W. Ingols, and Keith J. Piwowarski
U.S. Patent No.: 7,971,252
Date issued: 28 June 2011

Method and Apparatus Performing Automatic Mapping for a Multi-processor System
Nadya T. Bliss and Henry Hoffman
U.S. Patent No.: 7,983,890
Date issued: 19 July 2011

Architecture for Systolic Nonlinear Filter Processors
William S. Song
U.S. Patent No.: 8,005,176
Date issued: 23 August 2011

"First try, first light."

— Researchers working on the Space Surveillance Telescope sited at North Oscura Peak, New Mexico, 15 February 2011

Space Surveillance Telescope

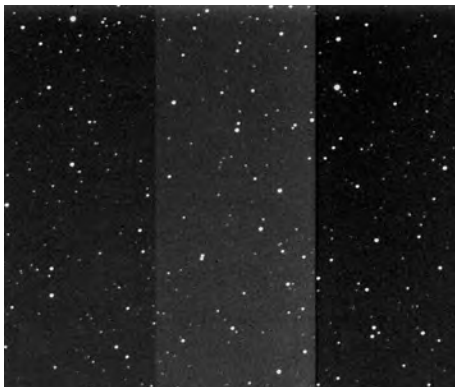
On 15 February 2011, researchers working on the Space Surveillance Telescope (SST) at North Oscura Peak in New Mexico sent a jubilant message to the SST sponsor and developers, "First try, first light!" This success was the culmination of several years of development.

Under sponsorship of the Defense Advanced Research Projects Agency (DARPA), the SST program was initiated in 2002 to develop and demonstrate technology for a new generation of very wide field-of-view, synoptic, space surveillance systems capable of achieving very high search rates, while maintaining adequate sensitivity to detect very small microsatellites at geosynchronous distances.

To meet these requirements, the SST required a 3.5 m telescope, much larger than the 1-meter-class ground-based electro-optical telescopes previously used. Because the optical design also had to maintain a very large field of view, an f/1 Mersenne-Schmidt design was selected, employing three mirrors, corrector optics, and a curved focal surface that is centrally located within the telescope structure.

To realize that curved-focal-surface detector, Lincoln Laboratory developed a unique, curved charge-coupled-device (CCD) imager that consisted of a large-format, full-frame, rapid-readout, low-noise imager that was conformally bonded to a curved silicon

ABOVE: A new observatory featuring a traditional rotating dome enclosure and an attached control building was constructed in 2010 to house the SST. The North Oscura site was chosen for this telescope because the mountaintop site provides pristinely dark, high-altitude observing.



ABOVE, CLOCKWISE FROM TOP: The fully assembled Space Surveillance Telescope (SST) at the mountaintop site; the ribbon-cutting ceremony for the SST was held on 12 October 2011. Cutting the ribbon are (from left to right) Eric Evans, Director, Lincoln Laboratory; General William Shelton, Commander, Air Force Space Command; and Regina Dugan, Director, DARPA; the SST's first-light image,15 February 2011.

mandrel. In 2011, a number of these imagers were meticulously assembled into a focal-surface mosaic. Because of the SST's extremely fast optical system, conformance of the mosaic of imagers to the ideal focal surface had to be extremely precise.

Full-frame imagers help maximize the SST field of view; however, that choice necessitates the use of a shutter to control exposure length. The location of the sensor inside the telescope structure required development of a unique, compact, high-speed shutter that did not impinge upon the light path while operating.

The telescope was constructed by L-3 Brashear. The SST's control and data processing systems leverage the legacy of Lincoln Laboratory, using the best algorithms and techniques originally developed for other programs. SST takes automated operation to the next level through the extended automation of the enclosure and facility infrastructure so that the SST can be operated safely and reliably from a remote location.

Following first light, the sensor system and telescope will undergo tuning to optimize performance of the imaging system, finalize focus and alignment of the telescope optical assemblies, and optimize the dynamic performance of the entire telescope assembly. These activities will be followed by an extended operational demonstration for DARPA. The SST will then be operated as a contributing sensor to the Space Surveillance Network while Air Force Space Command prepares to transition the system for dedicated operation in the Network.

Imaging System for Immersive Surveillance

The Imaging System for Immersive Surveillance (ISIS), sponsored by the Department of Homeland Security Science and Technology Directorate, is a novel, 360° video surveillance system that supports real-time and forensic situational awareness. Designed for protection of densely populated critical infrastructures, such as urban centers or transportation facilities, the ISIS video sensor achieves hundreds of millions of pixels of video coverage. While current-generation video surveillance systems are limited by gaps in camera coverage and inadequate resolution over large areas, ISIS supports comprehensive high-resolution wide-area coverage at centimeter-class resolution from a single vantage point.

The ISIS Spiral 1 sensor has been in operational testing since December 2009 at Logan Airport's Terminal A.

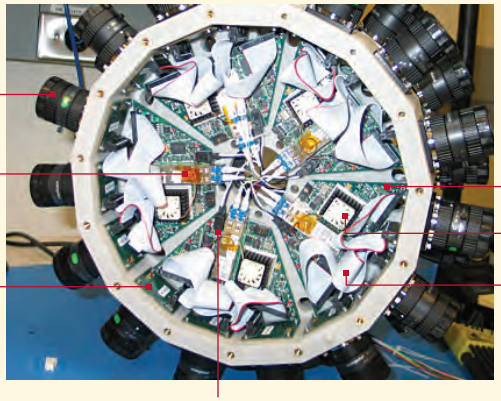
ISIS processes the video data by using a parallel processing architecture that processes the data in real time and presents it to the user over a networked interface. The ISIS multi-analyst interface and data storage solution provide virtual pan/tilt/zoom and video analytics that allow operators to cue in on scene features or time spans of interest.

In 2011, in partnership with Pacific Northwest National Laboratory, who provided program management, Lincoln Laboratory continued operational testing of ISIS at Boston Logan International Airport in collaboration with the Massachusetts Port Authority. Fabrication and development of the next-generation ISIS sensor, called Chandelier, continued with operational testing of the sensor in February 2011. Chandelier features over twice the resolution of the first-generation ISIS system currently installed at Logan Airport, in a smaller form factor and at higher frame rates. Chandelier will be installed at various test sites in fall and winter 2011.

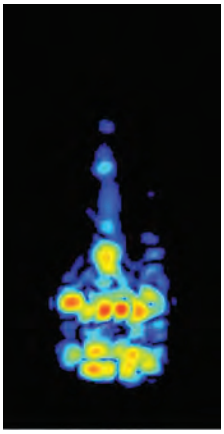
ISIS components

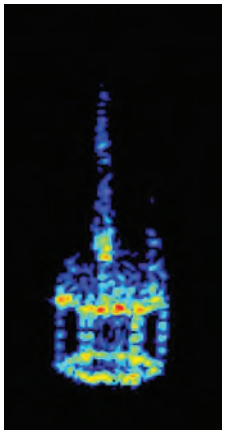
Chandelier

Chandelier components



Camera head assembly





Millimeter Wave Radar Upgrade

The Millimeter Wave (MMW) radar at the Reagan Test Site (RTS) on the Kwajalein Atoll, Marshall Islands, was upgraded from 2 to 4 GHz bandwidth and made operational in March 2011 after the installation and testing of new hardware. The expanded bandwidth increases the radar image resolution from 12 cm to 6 cm, as indicated in the simulated satellite pictures above, making MMW the highest-resolution satellite-imaging radar in the world by a factor of 2.

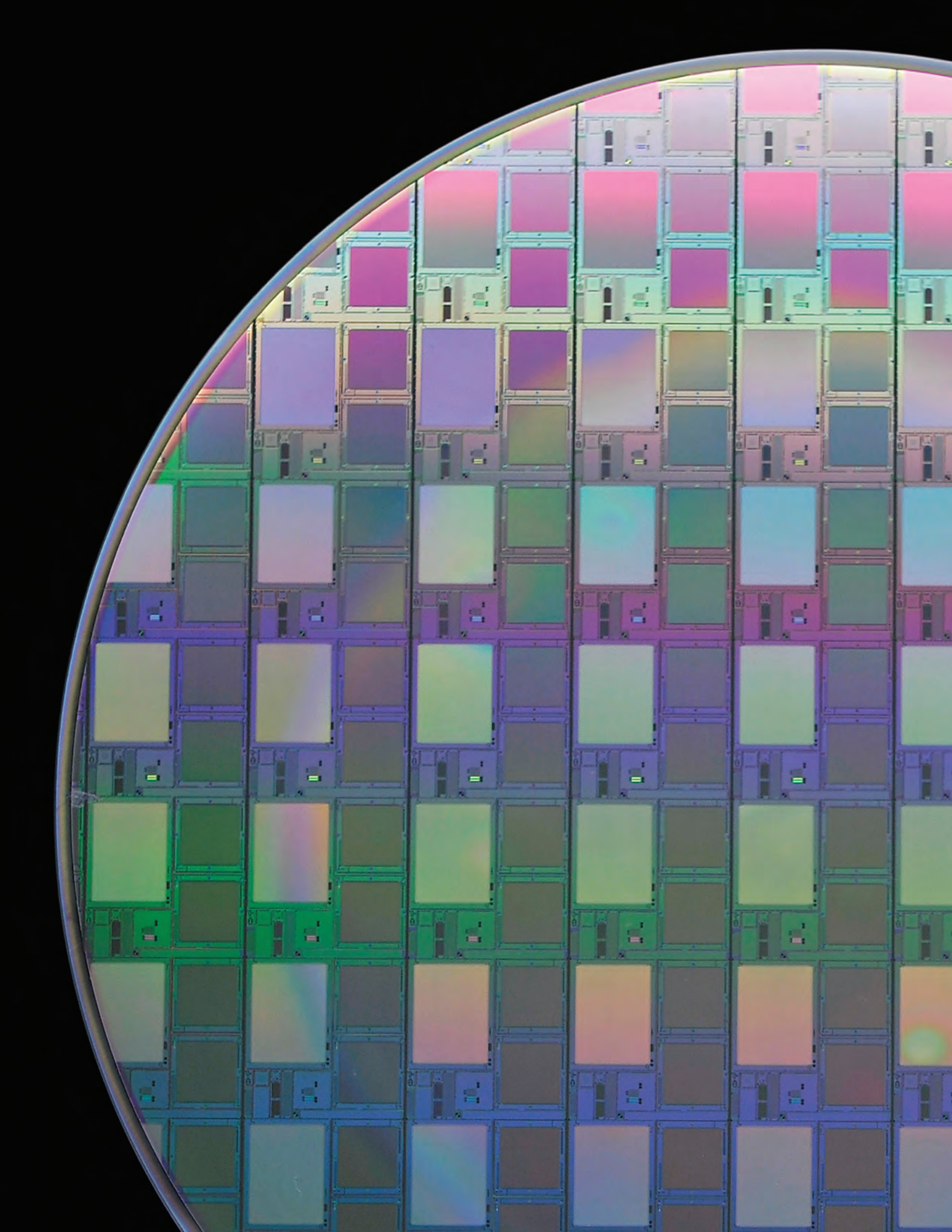
Initiated in 2005 by the U.S. Army RTS and managed by Lincoln Laboratory, the project to double the bandwidth involved the design and fabrication of a new 4 GHz transmitter tube, an enhanced receiver, and a Laboratory custom-designed upgrade to the radio-frequency (RF) path. The new hardware provides an increase in average transmit power and a reduction in noise figure in the receiver that double the tracking range of the MMW radar. An ongoing project to upgrade the data processing hardware and to utilize Radar Open Systems Architecture (ROSA) II software running on modern computers will double the data throughput of the radar, providing a capability to capture ultrahigh-resolution 4 GHz bandwidth imaging data on objects as large as 60 meters.

System Specifications		
Capability	**Before upgrade**	**After upgrade**
Maximum bandwidth	2 GHz	4 GHz
Range resolution	12 cm	6 cm
Imaging range window	37.5 m	63 m
Pulse width	50 μsec	100 μsec
Maximum pulse repetition frequency	2000	2000

The higher-bandwidth radar waveforms and enhanced image resolution enable improved data collection on space objects. Space-object-identification data collected by the Space Surveillance Network's imaging radars provide imagery of near-Earth satellites. The ongoing evolution to smaller payloads and the need for higher-fidelity images on larger payloads motivated this upgrade to the MMW, a contributing sensor in the Space Surveillance Network.

ABOVE LEFT: Millimeter Wave radar on Kwajalein Atoll.

ABOVE RIGHT: The MMW upgrade from 2 GHz to 4 GHz bandwidth increases image resolution as seen above in the simulated images of a satellite (4 GHz image on right).

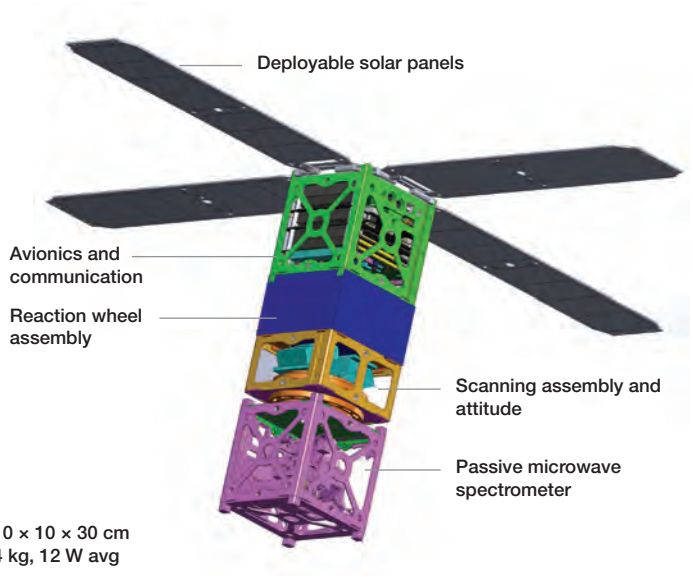


MISSION AREAS 25

THIS PAGE: Lithography process development for sub-90 nm features on 200 mm–diameter silicon wafer. Read more about the Advanced Technology mission on page 38.

SPACE CONTROL

Lincoln Laboratory develops technology that enables the nation's space surveillance system to meet the challenges of space situational awareness. The Laboratory works with systems to detect, track, and identify man-made satellites; performs 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 emphasis is the application of new components and algorithms to enable sensors with greatly enhanced capabilities and to support the development of net-centric processing systems for the nation's Space Surveillance Network.



This rendering shows an MIT and Lincoln Laboratory computer-aided design of a passive microwave sounder concept packaged in a nanosatellite (CUBESAT) form factor.

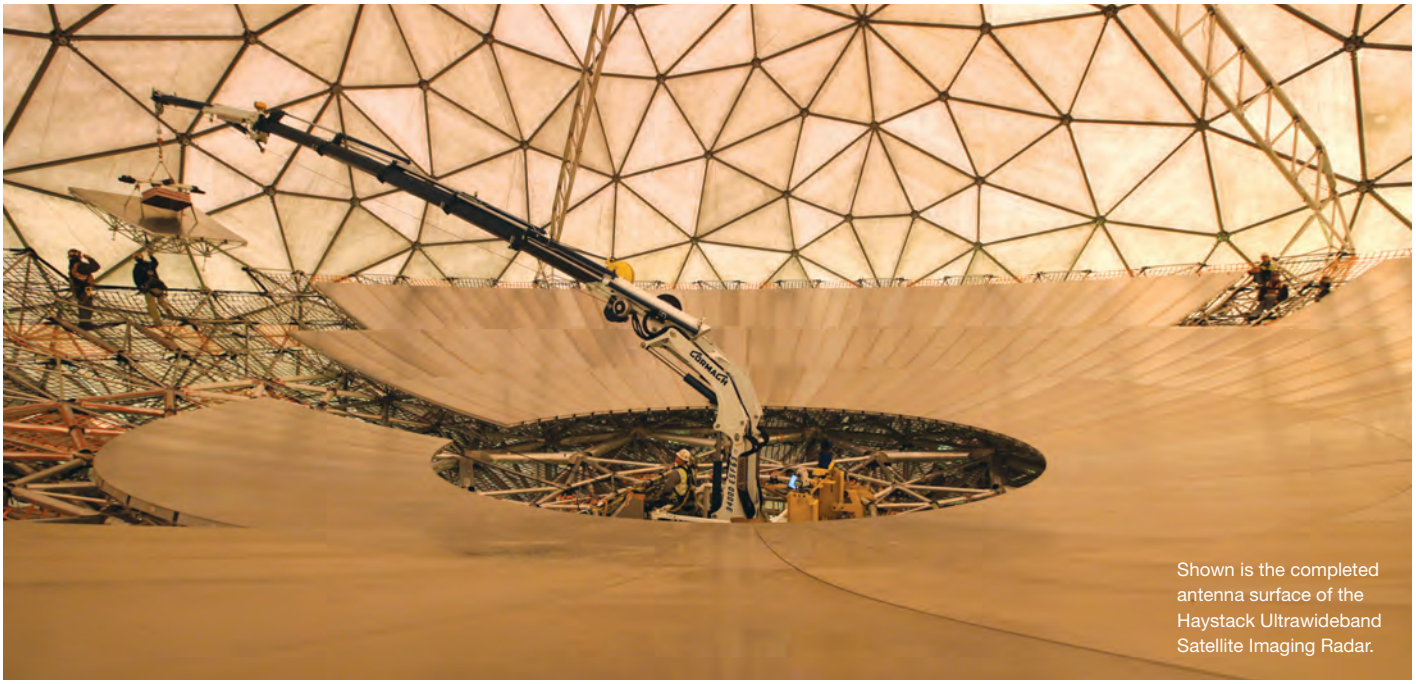
PRINCIPAL 2011 ACCOMPLISHMENTS

- In September 2010, the Space-Based Space Surveillance (SBSS) satellite was launched from Vandenberg Air Force Base. This satellite, built by Boeing and Ball Aerospace, is based on technologies and techniques demonstrated in the Laboratory's Space-Based Visible (SBV) program, which developed a contributing, operational sensor for the Space Surveillance Network between 1997 and 2008. In addition, the Laboratory provided SBSS with operational software, developed under the Optical Processing Architecture at Lincoln (OPAL) program, for mission planning and data processing. SBSS will provide significant capability improvement to the nation's space situational awareness capability.
- Continuing its history of developing passive microwave remote sensing systems and exploitation algorithms, the Laboratory explored novel concepts for hyperspectral microwave sounding. This year, the first CUBESAT bus and payload concept were developed.
- The Laboratory, leveraging its accomplishments on the Extended Space Sensors Architecture Advanced Concept Technology Demonstration, is now working with the Air Force and the broader space community on incorporating the lessons learned into a comprehensive net-centric system for meeting space surveillance needs.
- Lincoln Laboratory contributed significantly to the development of the overall system architecture for the nation's space control capability. Analyses and results are heavily influenced by experiments with prototype hardware, algorithms, and software systems. Close connections to the operations and the user community allow implementation of real user needs into the emerging architecture.
- The Space Surveillance Telescope, a unique 3.5 m telescope, designed and developed to synoptically search deep space for microsatellites, achieved first light in February 2011 (see page 20 for more on the telescope).


Dr. Grant H. Stokes


Mr. Lawrence M. Candell


Mr. Craig E. Perini


Shown is the completed antenna surface of the Haystack Ultrawideband Satellite Imaging Radar.

- The Haystack Ultrawideband Satellite Imaging Radar (HUSIR) will enable imaging of satellites in low Earth orbits with much higher resolution than currently possible. In 2011, the installation and initial alignment of the new antenna surface was completed. HUSIR will begin W-band satellite imaging operations in 2013 after integration and testing of the X- and W-band transmitters and receiver electronics.

FUTURE OUTLOOK

- New sensor systems are bringing expanded capabilities to the Space Control mission area. These systems include the Space-Based Space Surveillance–Block 10, the Space Surveillance Telescope, HUSIR, and the Space Fence. Considerable effort will be required to fully assess the information available from the new sensors and make it most useful to operators.

- Major activities will move toward information extraction, integration, and decision support. The challenge will be to incorporate the widest possible set of data and automate the process of generating customized, actionable products for a wide range of users. In particular, developing and demonstrating a net-centric architecture for information integration and command and control will be critical for evolving to a machine-to-machine–driven space situational awareness capability that can respond on timelines required to support survivability efforts.

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

AIR AND MISSILE DEFENSE TECHNOLOGY

Lincoln Laboratory develops and assesses integrated systems for defense against ballistic missiles, cruise missiles, and air vehicles in tactical, regional, and homeland defense applications. Activities include the investigation of system architectures, development of advanced sensor and decision support technologies, development of flight-test hardware, extensive field measurements and data analysis, and the verification and assessment of deployed system capabilities. A strong emphasis is on rapidly prototyping sensor and system concepts and algorithms, and on transferring resulting technologies to government contractors responsible for developing operational systems.

The XTR-1 radar is installed on the stern of the *Pacific Tracker*. INSET: The *Pacific Tracker* during at-sea testing of the modified ship off the coast of Oregon. The XTR-1 is installed beneath the radome at the stern.

PRINCIPAL 2011 ACCOMPLISHMENTS

- Lincoln Laboratory made key contributions to the new phased adaptive approach in missile defense. In 2010, the Laboratory led an Airborne Infrared (ABIR) Alternatives Analysis Study, which formed the basis for key decisions regarding ABIR sensors, and assessed platform options. Prototype software for automated image processing and closed-loop tracking was developed. Successful flight-test demonstrations used a surrogate ground sensor.

- In the newly established role as Aegis Ballistic Missile Defense (BMD) Advanced Technology Development Agent, the Laboratory initiated an analysis to establish Aegis BMD system requirements and technology needs for future combat systems in compliance with the phased adaptive approach. Modeling and simulation tools for the Aegis Weapon System, as well as for current and prospective SM3 interceptors, are being applied to quantify system performance.

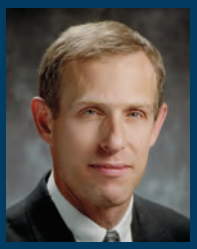
- The Laboratory is developing a design for a new airborne electro-optical/infrared tracking system. The system includes a large-aperture sensor with medium- and short-wave infrared and visible channels, as well as a processing architecture that uses an open, layered-element design. A successful preliminary design review was conducted in May 2010.

- Installation of the Laboratory-developed XTR-1 radar onto the Missile Defense Agency's *Pacific Tracker* was completed this year. The radar has an 11-meter dish and a two-frequency (X- and S-band) feed. XTR-1 and the two forward telemetry antennas will provide valuable data during testing of the Ballistic Missile Defense System.

- A major design and risk-reduction effort continued for a ship-based electronic countermeasure that will improve the Navy's capability to defend ships against advanced antiship missile threats. The Laboratory designed and built a prototype system and conducted an initial test campaign at a Navy field site at Dahlgren, Virginia.

- The Reagan Test Site Distributed Operations program achieved initial operations capability for distributed (Kwajalein; Huntsville, Alabama; and

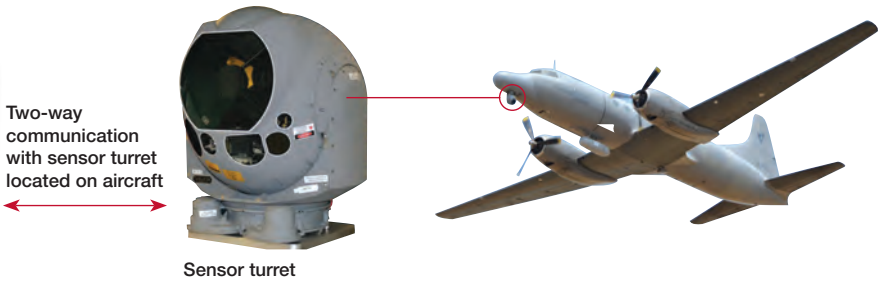

Dr. Hsiao-hua K. Burke


Dr. Andrew D. Gerber


Mr. Gerald C. Augeri

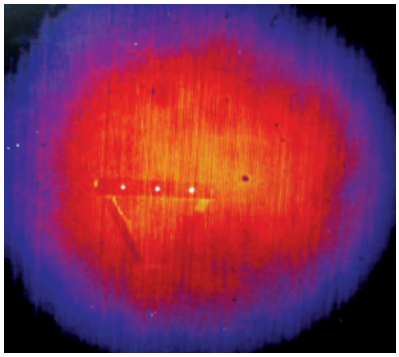

Mr. Dennis J. Keane


Airborne processor



ABOVE: In the Sensor Experimental System test facility, the Lincoln Laboratory prototype airborne processor is being integrated to a sensor turret (Raytheon's Multi-Spectral Targeting System). The turret is designed to integrate with a Reaper unmanned aerial vehicle to support passive infrared missile tracking for the Airborne Infrared program. The sensor turret is shown here on a manned aircraft for initial flight tests.

RIGHT: Infrared image created by the sensor. The Airborne Processor corrects the nonuniformity of the focal plane data and produces target detection and tracking information.



FUTURE OUTLOOK

Lexington, Massachusetts) operations in December 2011. A key enabler for full operation is a Pacific fiber-optic link from Kwajalein to Guam, which was emplaced in June 2010. A complete circuit connecting Kwajalein and Huntsville was established in fall 2010, and an Interim Authority to Operate at the classified level was granted in February 2011.

- Work began on an Office of Naval Research future naval capabilities program that will provide integrated hard-kill and soft-kill engagement scheduling for future shipboard combat systems. The Laboratory completed the design and coding, integrated the algorithms in a simulation test bed, and began generating performance results.

- Increasing vulnerability of deployed U.S. forces to large attacks by medium-range and intermediate-range ballistic missiles mandates greater emphasis on improving regional BMD battlespace and raid-handling capabilities. The Laboratory will have key responsibilities in both Aegis BMD and the Missile Defense Agency's (MDA) phased adaptive approach.

- The Navy and MDA are assessing how emerging sophisticated antiship missile threats may influence both Fleet operations and the need for improved air and missile defense capabilities. The Laboratory is helping with this assessment and with development and demonstration of near-term modifications for existing systems, as well as longer-term advanced capabilities, to respond to these threats.

- The Navy is looking toward developing advanced soft-kill capabilities to complement the hard-kill capabilities on which it has traditionally relied for ship self-defense, and toward providing better electronic protection for Navy radar and missile systems. The Laboratory is helping to shape a technology portfolio to ensure that electronic warfare capabilities are adequately addressed across naval platforms and weapons systems.

- To enhance the credibility of deployed missile defenses, ground and flight tests must be planned and instrumented to verify the models and simulations relied upon by warfighters. Lincoln Laboratory will continue to have a major role in test planning, test range and instrumentation improvements, and capability assessment.

COMMUNICATION SYSTEMS

Lincoln Laboratory is working to enhance and protect the capabilities of the nation's global defense networks. Emphasis is placed on synthesizing system architectures, developing component technologies, building and demonstrating end-to-end system prototypes, and then transferring this technology to industry for deployment in operational systems. Current efforts span all network layers (from physical to application), with primary focuses on radio-frequency military satellite communications, net-centric operations, free-space laser communications, line-of-sight networking, and human language technology.

RIGHT: Laura Elgin of the Optical Communications Technology Group adjusts the Lunar Laser Communication Demonstration transceiver module, a precursor to the unit that will fly aboard the spacecraft NASA is launching in 2013 to study the atmosphere and near-surface environment of the moon.

PRINCIPAL 2011 ACCOMPLISHMENTS

- Lincoln Laboratory performed an initial demonstration of a tactical radio test range that will provide comprehensive instrumentation and evaluation of emerging tactical communications systems and waveforms on ground and airborne mobile radio platforms.
- Technology development and flight experiments were completed for the Communications Airborne Layer Expansion Joint Capability Technology Demonstration.
- A disruption-tolerant networking protocol was adapted for multi-hop long-haul communication applications and was evaluated by using a transmission protocol network test bed to perform detailed characterization of the protocol over a wide range of link conditions.
- Field measurements to characterize optical atmospheric channels in a range of environments were performed in locations around the United States. A modeling tool was developed to help users analyze a variety of communication systems and link configurations.
- The Laboratory initiated proof-of-concept development of a small-form-factor, protected satellite communications (SATCOM) modem for ground-based SATCOM-on-the-move applications.
- Technology was developed to significantly increase SATCOM capacity via ground-segment communications processing enhancements.
- A new framework for speaker recognition achieved a fivefold reduction in equal error rate. It was transitioned to the Federal Bureau of Investigation (FBI) Forensic Audio, Video, and Image Analysis Unit.
- Biometric person-identification research and development were extended to include voice and face biometrics, and new face-comparison tools were transitioned to the FBI forensic analysis unit.
- The Laboratory extended the range of its multi-Gb/s air-to-ground laser communication system to >80 km over aggressive atmospheric channel conditions.
- Vocal biomarkers developed for depression monitoring were derived automatically from phonologically based measures of speech rate and showed stronger relationships with depression


Dr. J. Scott Stadler


Dr. Roy S. Bondurant


Mr. Stephan B. Rejto


Dr. Marc A. Zissman

Jeffrey Hall of the Wideband Tactical Networking Group operates the Portable Army Communications-on-the-move Terminal Block 1 mobile SATCOM terminal that demonstrates the ability to have mobile communications that are robust to disruption by jamming or other attacks.

One of the Advanced Multiband Communications Antenna Systems (AMCAS) is ready to undergo flight testing to demonstrate the viability of using low-profile antennas on widebody aircraft to achieve multi-Mbps communications via military satellite communications.

severity than previously reported for speech-rate measures.

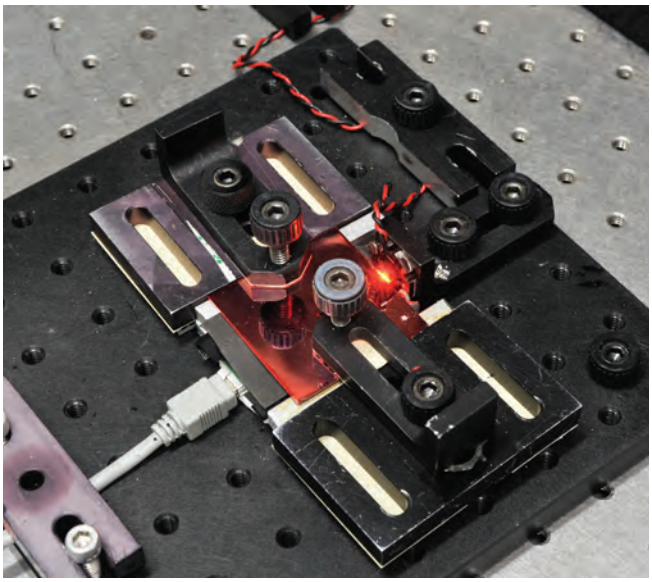
- The high-data-rate military SATCOM waveform that the Laboratory developed and demonstrated for intelligence, surveillance, and reconnaissance (ISR) readout was provided to more than 25 industry and government teams.
- Low-profile military SATCOM antennas for airborne applications were delivered to the Laboratory and flight tested.
- New technologies for net-centric operations include a framework that allows users to construct, share, and execute applications without programming and an architecture and prototype implementation that federates resource-brokering across mission areas.

FUTURE OUTLOOK

- Continued development of novel devices for optical communications will include a high-efficiency single-photon source; a high-efficiency, small size, weight, and power, flexible frequency/time modulator; and multimode receiver.
- Lincoln Laboratory's protected SATCOM terminals will continue to be used to control the nation's protected SATCOM constellation and to provide post-launch calibration of the Advanced Extremely High Frequency (AEHF) satellites.
- Ground-based dynamic resource allocation concepts that dramatically increase the capacity of protected SATCOM systems will be demonstrated.
- The Laboratory will extend its work on machine translation and document analysis to enable effective cross-language search and information retrieval from foreign-language documents by analysts operating in English.
- A ground mobile terminal capable of connecting to the recently launched AEHF satellite will be completed and demonstrated. This vehicle also has real-time connection to a network emulation test bed that illustrates the effects and interactions of multiple terminals.

CYBER SECURITY

Lincoln Laboratory conducts research, development, evaluation, and deployment of prototype components and systems designed to improve the security of computer networks, hosts, and applications. A particular focus is the intersection between the Laboratory's traditional mission areas and the cyber domain. Efforts include cyber analysis; creation and demonstration of robust architectures that can operate through cyber attacks; development of prototypes that demonstrate the practicality and value of new techniques for cryptography, cyber sensing, automated threat analysis, anti-tamper systems, and malicious code detection; demonstrations of the impact of cyber on traditional tactical systems; quantitative, repeatable evaluation of these prototypes; and, where appropriate, deployment of prototype technology to national-level exercises and operations. The Laboratory develops and deploys control and traffic-generation software for many of the Department of Defense's largest cyber ranges.



Lincoln Laboratory researchers are developing an open architecture for providing tamper resistance to hardware and software systems. Physically unclonable functions are used to embed cryptographic key material in a coating around a computing module (as shown here), permitting detection of tampering.

PRINCIPAL 2011 ACCOMPLISHMENTS

- Lincoln Laboratory developed a framework to permit live migration of mission-critical applications across heterogeneous platforms. The system enables fast, automatic switching of an application to diverse hardware and operating systems, providing cyber survivability through platform diversity.

- Context-enriched analysis and display capabilities were developed that provide national-level cyber situational awareness for cyber-threat operations centers. High-speed analysis techniques providing characterization of large-volume cyber data through the use of a historical behavioral context have been deployed for operational evaluation. Cyber tools to fuse and visualize cyber threats in the context of organizational mission and tasking priorities have been developed and are in operational use.

- The Laboratory is developing a tool that can automatically modify field-programmable gate array (FPGA)–based cores to improve their resistance to differential power analysis. The tool will eventually permit system developers to trade cost for security, depending on the intended use of the system and the threat environment.

- The Laboratory developed a suite of tools to automatically analyze malicious software. The Lincoln Automated Malicious Binary Data Analyzer (LAMBDA) is a malicious software triage system that incorporates many diverse software analysis tools into an automated workflow and produces an aggregated analysis result. The Laboratory has also developed a whole-system information-flow tracking tool that allows an analyst to mark chosen information in memory as tainted, then later identify the effects of program execution on the tainted data. These tools have been used effectively to analyze thousands of malicious software samples.


Dr. Marc A. Zissman


Dr. Robert K. Cunningham


Mr. Lee M. Rossey


Mr. Joshua W. Haines


Dr. William W. Streilein


Reed Porada and Tim Braje use the Lincoln Adaptable Real-time Information Assurance Testbed (LARIAT) to evaluate the effectiveness of cyber defense techniques.

FUTURE OUTLOOK

- As part of its cyber range support efforts, the Laboratory developed a technique for high-fidelity, low-level instrumentation of systems under test. Instrumentation at the hardware level permits observation of the internal state of the system without injecting events or leaving artifacts that can change the system's operation. Software processing engines convert the raw data to high-level application-specific events, which are input to analysis tools for cyber testing and verification, reverse engineering, and defensive detection.

- Lincoln Laboratory will continue to analyze mission-critical systems to ensure operations in a contested cyber domain. During the next year, the Laboratory will complete assessments of two space systems and an enterprise information system.

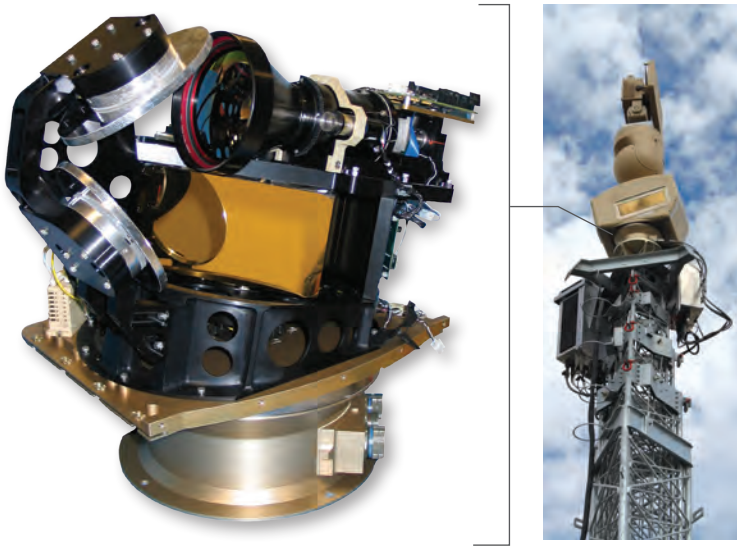
- Work will continue on expanding the depth and breadth of the cyber tests the Laboratory conducts and supports. The set of special-purpose tools required for these tests will be extended. Testing will expand into the area of design-time analysis, including examination of cryptographic proofs for correctness.

- Using its connection to the Department of Defense's Information Operations (IO) Range, the Laboratory will support evaluations of critical cyber tools. The IO Range permits DoD organizations to leverage diverse, unique cyber test assets, distributed at sites throughout the United States, in a location-transparent manner.

- The Laboratory will continue to architect and implement solutions for securing communications of modern tactical applications (such as unmanned aerial systems and mobile receivers) in dynamic mission environments, ensuring the resulting security solutions are easy for warfighters to use, satisfy existing security policies, and require little bandwidth and energy.

INTELLIGENCE, SURVEILLANCE, AND RECONNAISSANCE SYSTEMS AND TECHNOLOGY

To expand intelligence, surveillance, and reconnaissance (ISR) capabilities, Lincoln Laboratory conducts research and development in advanced sensing, signal and image processing, automatic target classification, decision support systems, and high-performance computing. By leveraging these disciplines, the Laboratory produces novel ISR system concepts for both surface and undersea surveillance applications. Sensor technology for ISR includes passive and active electro-optical systems, surface surveillance radar, radio-frequency (RF) geolocation, and undersea acoustic surveillance. Increasingly, the work extends from sensors and sensor platforms to include the processing, exploitation, and dissemination architectures that connect sensors to operational users. Prototype ISR systems developed from successful concepts are then transitioned to industry and the user community.



The Wide-area Infrared System for Persistent 360° Surveillance provides situational awareness in support of force protection applications. The sensor shown at left is secured inside a housing that is then mounted on a tower for surveillance applications.

PRINCIPAL 2011 ACCOMPLISHMENTS

- In support of national needs for wide-area persistent surveillance, the Laboratory continued to develop and demonstrate end-to-end systems for collection and exploitation of wide-area motion imagery data. The Laboratory conducted airborne testing with gigapixel-class visible and infrared sensors coupled with onboard data processing and a ground exploitation tool set. The processing and exploitation systems were deployed to a forward operating location.

- The Laboratory developed a high-resolution, long-wave infrared immersive video system that supports day/night force protection. The Wide-area Infrared System for Persistent 360° Surveillance (WISP-360) effort includes rapidly developing a custom sensor, as well as developing the processing and exploitation software. The system will provide context and cueing for other ISR sensors, and long-term data storage for forensic exploitation.

- The Airborne Ladar Imaging Research Testbed (ALIRT) system was integrated onto a government-furnished aircraft and delivered to a sponsor for operational use. A next-generation ladar system with enhanced sensitivity and discrimination performance is under development for foliage penetration and other missions.

- The Laboratory continued to develop novel radar discrimination modes for fixed and moving surface targets. Additional experimentation resulted in the refinement of signal processing algorithms and enhancements that increase system robustness to RF interference.

- The Laboratory developed and initiated deployment of a real-time fused situational awareness software application for manned and unmanned aircraft ISR missions. The open architecture specifications, standards, and technologies are serving as a prototype for future networked ground stations and exploitation applications.

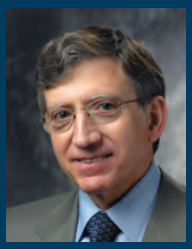
- The Laboratory has developed technology for the use of unmanned undersea vehicles (UUVs) in antisubmarine warfare. Autonomous detection algorithms that process UUV sensor array data to produce contact reports were developed, implemented, and tested in at-sea experiments.

- Development began on a prototype software suite for automated exploitation of persistent wide-area surveillance


Dr. Robert T-I. Shin

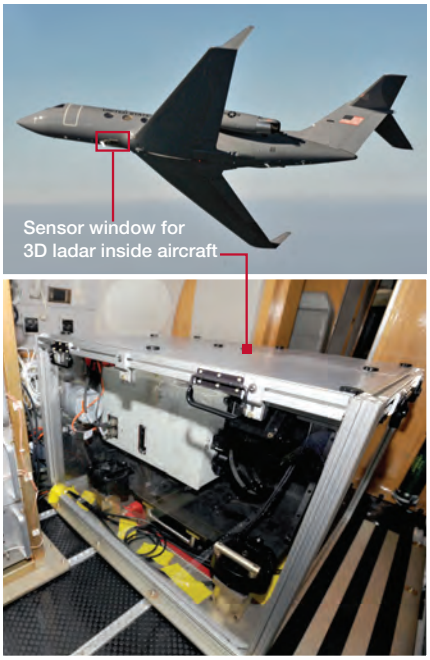

Dr. Robert G. Atkins

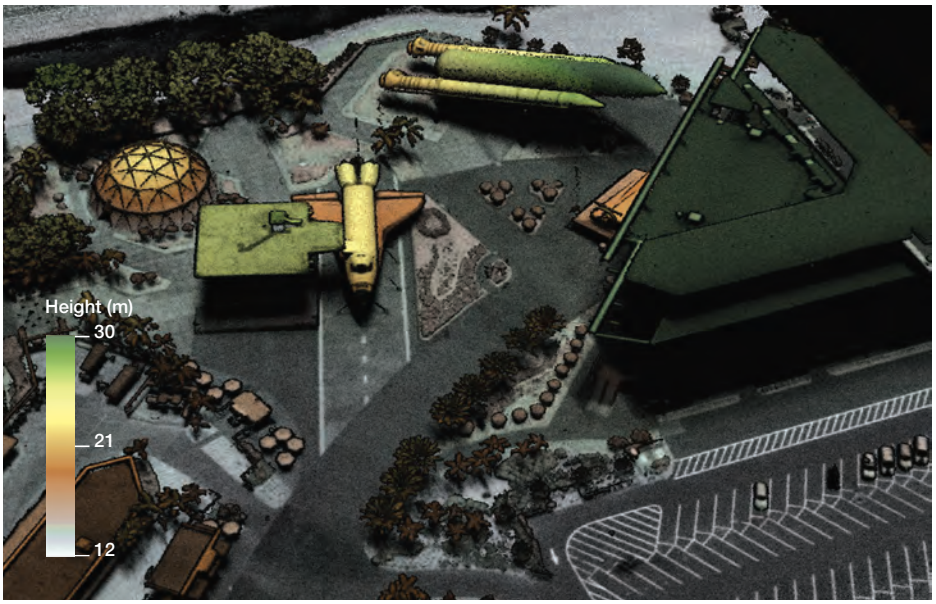

Mr. Robert A. Bond


Dr. Curtis W. Davis III


Dr. James Ward


Dr. William D. Ross





The 3D imagery of the Space Shuttle Explorer at the Kennedy Space Center complex in Florida was created from data acquired by the Airborne Ladar Imaging Research Testbed (ALIRT) system, shown at left.

FUTURE OUTLOOK

sensor data. This work includes advanced moving target tracking algorithms, machine learning of vehicle behavior patterns, and automated detection of anomalous activity. This activity-based analytics software was shown to be useful in increasing the throughput of ISR analysts. The initial version was transitioned to government users, and research is continuing.

- The Laboratory developed and tested an adaptive-data-rate, medium-range (100 m–1 km) RF data link that supports data rates from 1 Mb/s up to 1.9 Gb/s. This system uses advanced multiple-input, multiple-output techniques and very-high-performance adaptive space-time coding. The system sets new standards for non-line-of-sight, low-power communication links and enables efficient data exchange among ground-based distributed ISR systems.

- Increasing national investment is expected for developing and fielding improved systems for irregular and conventional warfare. As next-generation, wide-area, high-resolution sensors proliferate, additional emphasis will be on improved architectures for processing, exploitation, and dissemination. The ISR program is expected to continue to develop automated exploitation techniques and data-mining software tools for single- and multi-source ISR data. The Laboratory anticipates research and development to address difficult target sets for which improved sensing capabilities are needed: individuals in urban areas, targets under foliage, quiet submarines under the sea, and deeply buried facilities.

- There will be increased opportunity for synergy between the ISR Systems and Technology and the Cyber Security mission areas. Many ISR data exploitation techniques for threat network detection, as well as their required high-performance computing technologies, have direct application to cyber security problems such as cyber situational awareness. As the computing capability of smartphones and the wireless networking of laptop computers evolve, the ISR Systems and Technology mission will need to develop advanced capabilities to keep pace with this evolution.

TACTICAL SYSTEMS

Lincoln Laboratory assists the Department of Defense in improving the acquisition and employment of various tactical air and counterterrorist systems by helping the U.S. military understand the operational utility and limitations of advanced technologies. Activities focus on a combination of systems analysis to assess technology impact in operationally relevant scenarios, rapid development and instrumentation of prototype U.S. and threat systems, and detailed, realistic, instrumented testing. A tight coupling between the Laboratory's efforts and the DoD sponsors and warfighters involved in these efforts ensures that these analyses and prototype systems are relevant and beneficial to the warfighter.

The Ku-band radar is currently in development.

PRINCIPAL 2011 ACCOMPLISHMENTS

- The Laboratory continued a comprehensive assessment of U.S. Air Force airborne electronic attack options against foreign air defenses. Systems analysis, detailed radar and electronic protection system modeling, and testing of electronic attack systems informed acquisition decisions regarding next-generation electronic attack systems.

- Capabilities of the Laboratory's Airborne Countermeasures Test System aircraft were enhanced to support captive-carry testing of threat representative electronic attack emulators and testing for advanced U.S. fighter aircraft radar development.

- Detailed assessments of digital RF memory–based electronic attack impacts on air-to-air weapon systems were continued. Flight testing, systems analysis, and hardware-in-the-loop simulation enabled improvement of U.S. electronic protection systems, and informed Department of Defense leadership involved in making decisions on future investments.

- The Laboratory conducted an evaluation of the capabilities and limitations of infrared sensors and seekers to support passive air-to-air engagements.

- Assessments that examined the impacts of advanced military system export were used by 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.

- The Laboratory evaluated threats to U.S. space systems and assessed measures to preserve capabilities in the face of these threats.

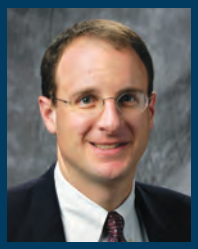
- Work continued on advancements to several innovative airborne signals intelligence (SIGINT) capabilities. In collaboration with the user community, the Laboratory operationally demonstrated prototypes. The technology is being transitioned to industry for use in next-generation advanced SIGINT systems.

- The Laboratory developed a novel robot-mounted sensor system used by engineer teams for route-clearance applications. Enhancements supporting additional applications are also in development.

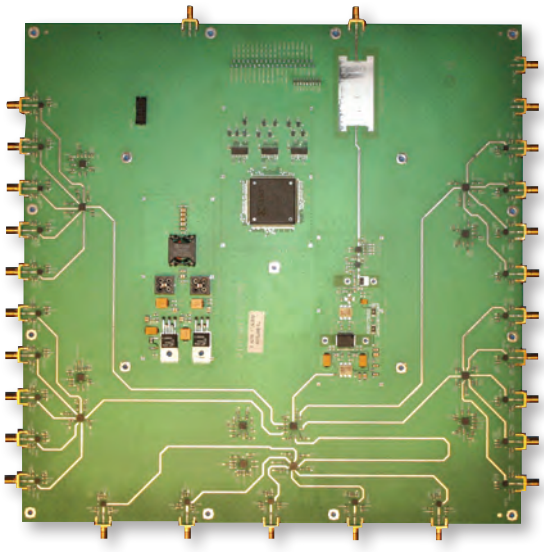

Dr. Robert T-I. Shin

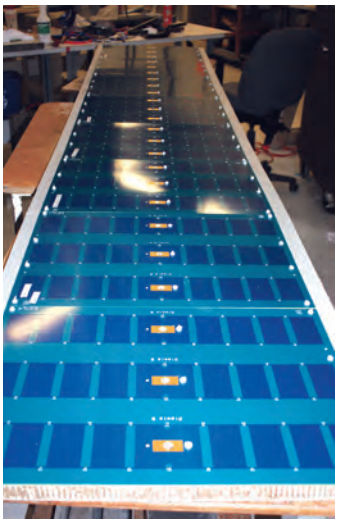

Dr. Robert G. Atkins

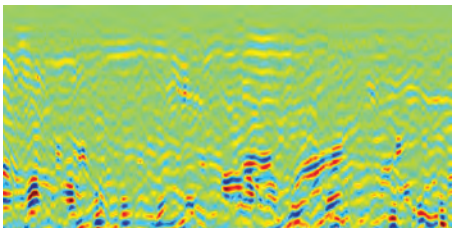

Dr. Justin J. Brooke


Dr. Kevin P. Cohen


Dr. Melissa G. Choi







LEFT: The Laboratory is leveraging fundamental strengths in systems analysis, radar design, antenna array development, and tactical data processing to develop a novel approach to ground-penetrating radar (GPR) technology.

ABOVE: The GPR trace image was created by the system at left.

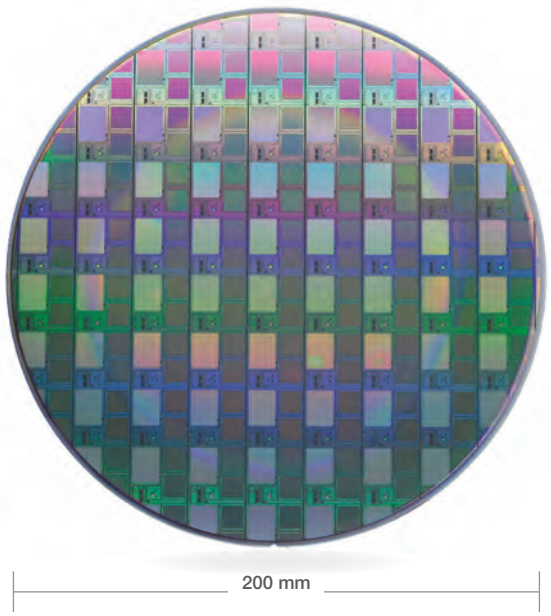
- Advanced architectures and technologies were transitioned to the next generation of counter–improvised explosive device electronic attack systems.
- Support continued for two novel airborne sensor systems that are elements of a fielded, quick-reaction, multiple-intelligence capability for intelligence, surveillance, and reconnaissance (ISR).
- The Laboratory innovated a ground-penetrating radar technology for counterterrorism applications. Significant antenna array and processing advances were demonstrated, and a field-worthy prototype is in development.

FUTURE OUTLOOK

- A current, renewed emphasis on threat prototyping will continue and will be leveraged to better inform Department of Defense acquisition decisions.
- Support to the U.S. Air Force will expand in the key area of information dominance. Efforts will inform the development of new capabilities for evolving threats, and the refresh of current ISR capabilities.
- A new Advanced Concepts and Technologies Team initiated for the Air Force will grow to provide increased advanced concept innovation in novel sensors and systems for enhanced air vehicle survivability.
- To address current needs and changing acquisition paradigms, the Laboratory will continue to extend its rapid development capabilities.
- Counterterrorism efforts will increase, with greater emphasis on the development and demonstration of ISR architectures.

ADVANCED TECHNOLOGY

Research and development in Advanced Technology focus on the invention of new devices, their practical realization, and their integration into subsystems. Although many devices continue to be based on solid-state electronic or electro-optical technologies, recent work is highly multidisciplinary, and current devices increasingly exploit biotechnology and innovative chemistry. The broad scope of work includes the development of unique high-performance detectors and focal planes, three-dimensional (3D) integrated circuits, biological- and chemical-agent sensors, diode lasers and photonic devices using compound semiconductors and silicon-based technologies, microelectromechanical devices, radio-frequency (RF) components, unique lasers including high-power fiber and cryogenic lasers, and quantum logic in both superconducting and trapped-ion forms.



Lithography process development for sub-90 nm features on 200 mm diameter silicon wafers is ongoing in the upgraded Microelectronics Laboratory.

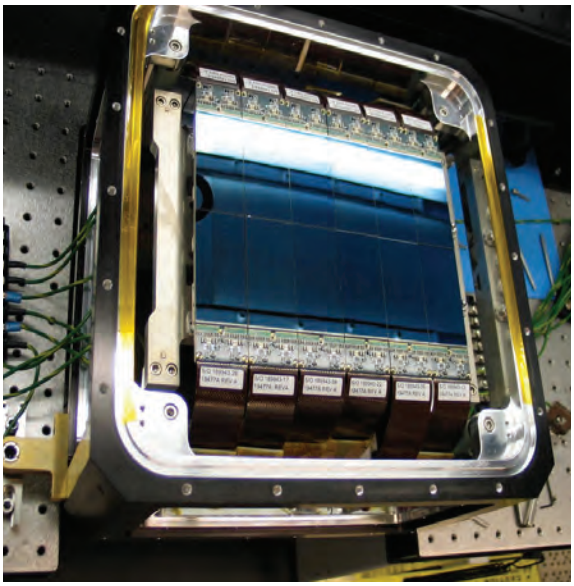
PRINCIPAL 2011 ACCOMPLISHMENTS

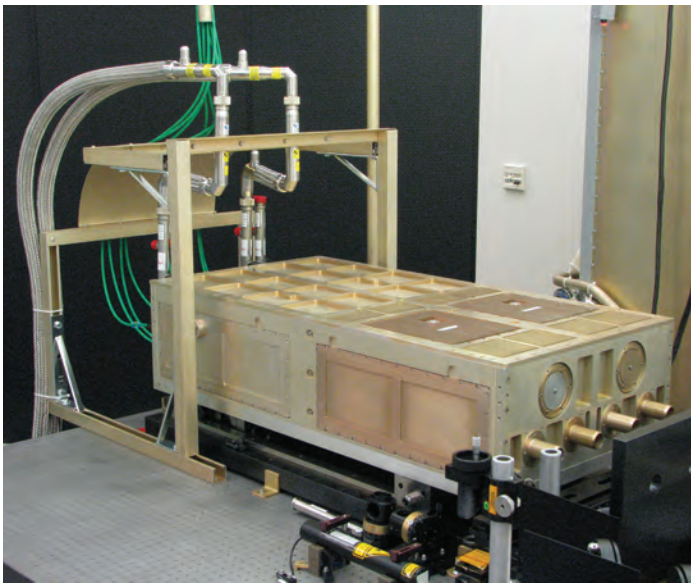
- A cryogenically cooled Yb:YAG amplifier with a fiber-based seed laser demonstrated 40 mJ output (80 W, average power) in 15 ps pulses at 2 kHz pulse-repetition rate. This joint effort with MIT Research Laboratory of Electronics is targeted at sources for extreme ultraviolet lithography and hyperspectral radiography.
- An eight-element array of 0.5 kW commercial optical-fiber amplifiers was used in a master-oscillator power-amplifier architecture with phase control by the stochastic parallel-gradient-descent algorithm to reach 4 kW of coherent output power.
- Quantum-cascade lasers in a master-oscillator power-amplifier architecture have achieved 1.5 W output power at 7.26 μm wavelength in single-longitudinal/single-transversal mode. Operation was at 300 K temperature under pulsed conditions (20 kHz/100 ns). This collaboration with Harvard University is yielding bright mid-infrared sources suitable for field-portable applications.
- Backside-illuminated charge-coupled-device (CCD) imagers have been assembled onto a 5.44 m radius spherical focal surface with better than 5 μm accuracy. This imaging array has been qualified and saw first light in the Space Surveillance Telescope (see page 20). This optical configuration enables fast optics with a short focal length.
- A slab-coupled optical waveguide (SCOW) laser previously invented at Lincoln Laboratory was configured in an external cavity and demonstrated the highest power and lowest relative intensity noise at 1.5 μm wavelength.
- Instrumented payloads for high-power characterization of the high-energy laser (HEL) on the Airborne Laser Testbed (ALTB), known as the Missile Alternative Range Target Instrument–High Power (MARTI-HP), were completed. Two MARTI-HP payloads were used on Black Brant rockets in successful HEL ALTB demonstrations.


Dr. David C. Shaver


Dr. Craig L. Keast


Dr. Charles A. Primmerman


The Space Surveillance Telescope's curved focal surface array made it possible to realize f/1 optics with a 3.5 m primary mirror in the observatory. The curvature of the constituent charge-coupled devices is conveyed by the apparent bending of the reflected fluorescent tube.


The cryogenically cooled Enhanced Track Illuminator Laser (ETILL) was developed for the Airborne Laser program. The hardware assembly and performance verification were completed in 2011.

- Compact, low-power transceivers for short-range point-to-point RF communication links have been demonstrated with thinned, bare commercial and custom integrated circuits (ICs).
- In spring 2011, a tool upgrade for the Microelectronics Laboratory was completed to covert from 150 mm diameter wafers and a 150 nm IC technology node to 200 mm diameter wafers and a 90 nm technology node (see page 13). Upgraded circuit processes were refined for CCD imagers and fully depleted silicon-on-insulator (FDSOI) ICs. The latter provide the basis for the 3D multiproject research foundry available to Department of Defense contractors.

FUTURE OUTLOOK

- Innovative solutions for emerging DoD needs are enabled by the Laboratory's competencies in imaging focal planes, silicon circuit technology using 3D integration, compressive receivers, optical lithography, lasers, photonic devices, and superconductive electronics, all supported by materials growth and device design, and test and packaging facilities.
- The scope of photon-counting focal-plane technology will continue to expand, with development of Geiger-mode detectors that operate for passive imaging.
- Significant effort to support DoD needs for high-energy lasers will be invested in cryo-cooled, slab-coupled, or fiber gain media with both spectral and coherent beam combining.
- Chemical and biological sensing technologies will be advanced for detection of explosives, toxins, and bioagents. Mid-infrared quantum cascade lasers will be matured for infrared countermeasures and chemical sensing.
- Biomolecular technologies will be exploited to create broad-spectrum antiviral therapies, to engineer proteins, and to create new energy sources.
- Size and speed scaling of silicon devices is slowing. Pathways "beyond silicon" will be explored: 3D mixed-material circuit integration, graphene electronics, and quantum information science.

HOMELAND PROTECTION

The Homeland Protection mission supports the nation's security by innovating technology and architectures to help prevent terrorist attacks within the United States, to reduce the vulnerability of the nation to terrorism, to minimize the damage from terrorist attacks, and to facilitate recovery from either man-made or natural disasters. The broad sponsorship for this mission area spans the Department of Defense, the Department of Homeland Security (DHS), and other federal, state, and local entities. Recent efforts include architecture studies for the defense of civilians and facilities against biological attacks, development of the Enhanced Regional Situation Awareness system for the National Capital Region, the assessment of technologies for border and maritime security, and the development of architectures and systems for disaster response.

Lincoln Laboratory is contributing to Rapid Area Sensitive-Site Reconnaissance (RASR) by developing autonomous systems (right) that link sensor measurements, such as chemical detection and imagery, and indoor mapping to enhance real-time situation awareness for first responders.

PRINCIPAL 2011 ACCOMPLISHMENTS

- The Next-Generation Incident Command System (NICS), initiated in partnership with the California Department of Forestry and Fire Protection, was evaluated by first responders in multiple operational settings, including wildland fires and large-scale floods. NICS enables collaborative command and control by integrating technologies such as resource tracking, full-motion video, and robust data communication. The DHS Science and Technology Directorate (DHS S&T) is leading research and development to integrate capabilities for the fire, law enforcement, emergency management, and National Guard communities.

- The Accelerated Nuclear DNA Equipment (ANDE) program, sponsored jointly by the Departments of Defense, Homeland Security, and Justice, is developing common, core, automated DNA analysis instrument prototypes that can be used by minimally trained personnel to produce five human DNA profiles from reference samples within one hour. The Laboratory, as the integrator and system architect, is working to improve forensic DNA sampling techniques to complement the planned ANDE capability, to provide oversight to the subcontractor developing the analytical instrument, and to develop a secure privacy-preserving framework for data processing, analysis, and storage.

- The Imaging System for Immersive Surveillance (ISIS) is being operationally tested with the Massachusetts Port Authority (see page 22 for more on ISIS).

- The Laboratory is developing a video analytics software prototype that performs an attribute-based search (e.g., hat, black jacket, blue jeans) and then generates a track of a suspect across arrays of security cameras.

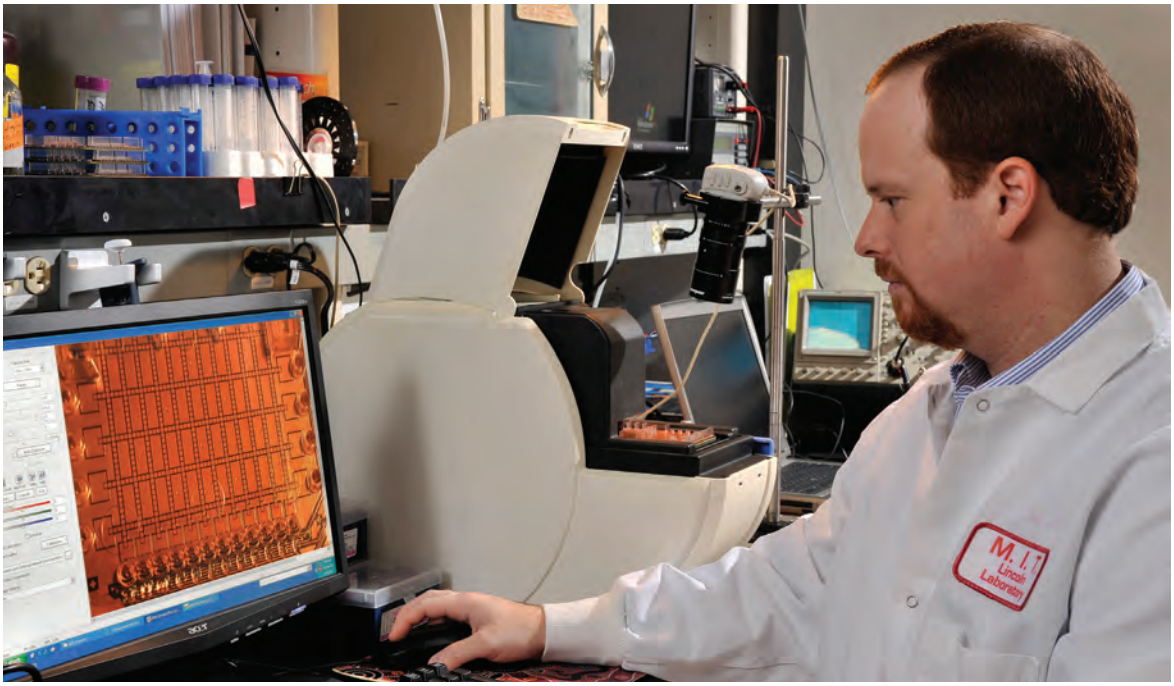
- The Laboratory continues to support the DHS in evaluating technologies for homeland air security. Key contributions include architectural development for high-fidelity modeling of emergent surveillance technologies that may be employed at border and interior locations.

- The Laboratory supported U.S. Coast Guard strategies during the Deep Water Horizon cleanup of the Gulf Coast oil spill. Oil-finding sensors were assessed for their resolution, coverage rate, and endurance to aid Coast Guard selection and deployment strategies.


Dr. Israel Soibelman


Mr. James M. Flavin


Dr. Timothy J. Dasey



Lincoln Laboratory is developing, integrating, and evaluating microfluidic systems to enable new capabilities in biometrics, forensics, synthetic biology, and biomedical applications. Dr. Jeffrey Palmer is evaluating the performance of a digital microfluidic platform (through a research collaboration with Advanced Liquid Logic) for use in the rapid DNA analysis program.

FUTURE OUTLOOK

- Under sponsorship of the DHS S&T, the Container Security Testbed (CSTB) for maritime cargo security was developed. The CSTB evaluates technologies for detecting trace chemical or biological signatures of hazardous materials.
- New biomedical initiatives emphasize medical diagnostics for the DoD and leverage Laboratory strengths in sensing, signal processing, algorithms, and data communications to develop technologies at molecular, cellular, and human system scales.
- For use in countering chemical threats, the Laboratory developed concepts of operation, conducted threat phenomenology measurements to assess military utility, performed tabletop exercises, and led development of a rapid fielding initiative.
- Securing and defending U.S. borders motivate the need for an integrated air, land, and maritime architecture. This need will spur advancements in wide-area sensors, such as over-the-horizon radar, as well as in advanced data fusion and decision support tools. Lincoln Laboratory will apply its strengths in advanced sensors, signal processing, service-oriented architecture, and rapid prototyping to provide these technologies.
- Analysis, development, and testing of advanced chemical and biological defense solutions will continue, with strong contributions in countering chemical threats.
- The Laboratory will provide next-generation biometrics and forensics technologies for theater and homeland security, including different sensing modalities, identification techniques, and fusion algorithms.
- In partnership with local, state, and federal operational communities, the Laboratory will develop and assess technologies and architectures to address critical infrastructure protection and disaster response. Solutions will leverage Laboratory strengths in netcentric architecture, sensors, and decision support.
- Activities with the U.S. Coast Guard will include assessments of sensors, development of decision support architectures, and evaluation of test beds for port security.

AIR TRAFFIC CONTROL

Since 1971, Lincoln Laboratory has supported the Federal Aviation Administration (FAA) in the development of new technology for air traffic control. This work initially focused on aircraft surveillance and weather sensing, collision avoidance, and air-ground data link communication. The program has evolved to include safety applications, decision support services, and air traffic management automation tools. The current program is supporting the FAA's Next Generation Air Transportation System (NextGen). Key activities include the operation of a national-scale integrated weather-sensing and decision support prototype, testing and technology transfer of a runway incursion-prevention system, development of a future air traffic control tower automation platform, and the development of a net-centric, system-wide information management system.

The Route Availability Planning Tool aids in reducing weather-related delays.

PRINCIPAL 2011 ACCOMPLISHMENTS

- The Route Availability Planning Tool (RAPT) was deployed to Chicago to facilitate airport departure management during severe weather conditions. A successful operational evaluation during the summer storm season demonstrated the capability to adapt the RAPT concept of operations to Chicago's four-corner-post environment. Ongoing RAPT operations in New York City provided high benefits in this most-delay-beset metroplex in the United States.

- The Tower Flight Data Management (TFDM) prototype developed by the Laboratory was deployed to Dallas/Fort Worth International Airport to support successful initial shadow evaluations of TFDM and the Staffed NextGen Tower (SNT) concept. TFDM and SNT significantly improve airport operations by providing high-quality situational awareness, cross-domain collaboration capabilities, and decision support automation. Digital flight data management, high-quality surface surveillance, runway usage and airport configuration predictions, and management of departure fix and overhead stream constraints are key aspects of the TFDM/SNT concept of operations.

- The Collaborative Storm Prediction for Aviation (CoSPA) system was successfully evaluated at congested en route and terminal air traffic control (ATC) facilities. CoSPA provides high-resolution convective weather forecasts with 0- to 8-hour look-ahead times, sufficient to support high-quality tactical and strategic ground-delay and rerouting decisions. On the basis of highly favorable evaluation results, CoSPA is expected to become a key component of the FAA's next-generation weather decision support environment.

- Lincoln Laboratory completed initial concept development and technology evaluations for a net-centric weather information system—NextGen Network Enabled Weather (NNEW). Demonstrations at the FAA Technical Center showed the benefits of the NNEW architecture. The Laboratory will facilitate NNEW implementation through technology transfer support, operational test and evaluation, and deployment support.

- The Runway Status Lights System (RWSL) continues successful operational evaluations at Dallas/Fort Worth, Los


Dr. Mark E. Weber


Mr. James M. Flavin


Dr. James K. Kuchar


Dr. Gregg A. Shoults


Dr. Marilyn M. Wolfson

The Tower Flight Data Management prototype was developed to explore new, more efficient air traffic control concepts.

Angeles, San Diego, and Boston airports. New concepts demonstrated included Final Approach Runway Occupancy Signals and Runway Intersection Lights. RWSL is slated for operational deployment at 22 airports in the United States.

- In support of the FAA's Traffic Alert and Collision Avoidance System program, the Laboratory developed extensive datasets, high-fidelity aircraft encounter models, and novel collision-avoidance algorithms to assess current alerting capabilities and next-generation concepts. The Laboratory also leads Department of Defense and Department of Homeland Security (DHS) efforts to address collision-avoidance issues limiting airspace access for unmanned aerial systems.

FUTURE OUTLOOK

- Lincoln Laboratory will support the FAA in refining concepts of operation and technology supporting future ATC tower surveillance, automation, and decision support. The Laboratory will support adaptation of the TFDM prototype system to additional airports, technology transfer, algorithm refinement, and benefits analysis for the FAA's TFDM program.

- The Laboratory will assume a lead role in concept development, prototyping, and implementation support for the FAA's NextGen Weather Processor (NWP). NWP will integrate weather processor functions currently performed by separate terminal, en route, and national domain systems, and will enable new capabilities such as CoSPA. NWP will interoperate with other ATC automation systems to integrate weather information into air traffic management decision making.

- Lincoln Laboratory's role in airspace access for unmanned aerial systems will continue to increase in importance. Sponsored programs from DoD, DHS, FAA, and NASA include analysis, simulation, architecture evaluations, and field demonstrations. The Laboratory's leadership in this area will be critical to multiple agencies in this high-priority mission.

- Support to the FAA will continue for critical infrastructure programs such as the Multifunction Phased Array Radar, System-Wide Information Management, NNEW, and Automatic Dependent Surveillance–Broadcast.

ENGINEERING

Fundamental to the success of Lincoln Laboratory is the ability to build hardware systems incorporating advanced technology. These systems are used as platforms for testing new concepts, as prototypes for demonstrating new capabilities, and as operational systems for addressing warfighter needs. To construct the variety of systems used in programs across all mission areas, the Laboratory relies on its extensive capabilities in mechanical design and analysis, optical system design and analysis, aerodynamic analysis, mechanical fabrication, electronics design and assembly, control system development, system integration, and environmental testing. These capabilities are centered in the Laboratory's Engineering Division, which is an important contributor to many of the Laboratory's most successful efforts.

Michael Stern is shown building thermoplastic parts using a fused deposition modeling production system located in the Laboratory's new rapid prototyping facility. The system is used to rapidly produce parts and iterate designs, including fabrication of functional parts using advanced high-strength materials.

PRINCIPAL 2011 ACCOMPLISHMENTS

- After the integration of the major subassemblies of the Haystack Ultrawideband Satellite Imaging Radar (HUSIR) antenna, the primary reflector surface, comprising 104 subframe and panel assemblies, was installed. The fine alignment of the antenna surface will allow efficient operation of the radar at W-band.
- Lincoln Laboratory began assembly, integration, and testing of the qualification version of a 5-inch optical module for high-data-rate laser communication from space. Following qualification module assembly, the flight version of the module for the Lunar Laser Communication Demonstration will be built.
- Laboratory engineers built an innovative system for detecting chemical or biological agents within shipping containers. The system, which is designed to be mounted on a large crane, was demonstrated on a crane test bed.
- An advanced laser radar system for ground mapping was integrated into a Gulfstream 3 aircraft for operational use.
- The Laboratory assembled and tested an enhanced track illuminator laser for the Airborne Laser Test Bed.
- The first phase in the development of an autonomous system for leading mounted patrols was completed. The system incorporates GPS waypoint following and automated station-keeping on a follower vehicle.
- Lincoln Laboratory successfully developed a state-of-the-art process for attaching ceramic column grid array devices to printed circuit boards for use in spacecraft. Samples were tested to failure, and the process was endorsed by outside experts.


Dr. Eliahu H. Niewood


Dr. William R. Davis


Dr. Michael T. Languirand

Cutting-edge high-speed five-axis machining technology enables rapid fabrication of complex mechanical components with extreme precision with a single setup process. This technology has many benefits, including simultaneous five-axis milling of complex surfaces, laser tool and part inspection, and reduction of errors in fabricating multiple copies of a single part type. Edison Arana is shown operating the Laboratory's recently purchased five-axis mill.

- Two new cleanroom facilities were constructed to support a growing number of satellite payload system developments. Both cleanrooms are in heavy use for the assembly of space-based optical systems.

- To further modernize the Laboratory's fabrication and assembly equipment, a custom-designed system for washing and cleaning printed circuit board assemblies, thermal cycling ovens, new thermal vacuum chambers, and a Nikon desktop scanning electron microscope were purchased.

FUTURE OUTLOOK

- A number of new space payload efforts are under way or recently begun. The Laboratory has significantly expanded its ability to develop these systems, with multiple teams working in parallel on different programs. Increasingly efficient execution of these efforts is attributed to the rapid dissemination of lessons learned from each program.

- A variety of efforts to further the underlying technology for mechanical and materials engineering are under way at the Laboratory. These include efforts to better understand the structural analysis and properties of bolted connections, to model solder and adhesive materials, and to develop a catalog of materials for electronics components, boards, and chassis with different coefficients of thermal expansion.

- The Laboratory is expanding the modernization of its fabrication and assembly equipment to include new infrastructure for environmental testing of mechanical systems as well as for assembly and testing of complex optical systems.

- Construction of a new rapid prototyping facility was completed. The co-location of engineering personnel, fabrication equipment, and integration and test areas enables the rapid development of new systems. The facility includes conventional machining equipment, an electronic assembly area, and a rapid fabrication equipment laboratory. The facility will support multiple Laboratory programs simultaneously.

LABORATORY INVOLVEMENT 47

THIS PAGE: Bill Delaney, Director's Office Fellow, talks to West Point cadets about upgrades to the Haystack long-range imaging radar. For more on Technical Education programs, see page 52.

Diversity and Inclusion

The broad range of experiences and perspectives of the staff strengthens Lincoln Laboratory's ability to develop multifaceted, innovative approaches to problems. Fostering a work environment that supports such diversity is core to the Laboratory's continued success. Ongoing initiatives are promoting a workplace that both seeks and appreciates the diverse talents and ideas of employees.

Special Diversity Presentations at Lincoln Laboratory

Disability Etiquette—Challenging Our Assumptions about People with Disabilities in the Workplace

In January 2011, the Diversity and Inclusion Office hosted a special presentation on disability awareness and etiquette. Michael Muehe, executive director of the Cambridge Commission for Persons with Disabilities, discussed how to conduct workplace interactions with people with disabilities.

My Life as a Tuskegee Airman

James A. Sheppard served with the 100th Fighter Squadron of the Army Air Force during World War II. The squadron trained at the Tuskegee Army Air Field in Alabama, and they, along with 996 other men who graduated from the program there, were known as the Tuskegee Airmen, the first African-American military pilots, navigators, and bombardiers. In February 2011, to a full house in the Laboratory's auditorium, Mr. Sheppard recounted his experiences flying missions over Europe and reflected on the post-war opportunities afforded to him because of his membership in this historic group of courageous combat airmen.

Lincoln Laboratory Technical Women's Network (LLTWN)

To promote the retention and achievement of women technical staff, LLTWN provides a forum for sharing strategies for success and a mentoring program that fosters career development. To acquaint staff with technology developments, monthly meetings often feature presentations by women researchers from Laboratory technical groups.

Lincoln Laboratory New Employee Network (LLNEN)

LLNEN helps new employees transition from their previous environments to the Laboratory and the region. By providing a social network for new employees, LLNEN encourages the retention of talented individuals. LLNEN also facilitates participation in professional development and community outreach opportunities.

In 2010, at an event coordinated by LLNEN, rotating teams of Laboratory volunteers spent three days helping Habitat for Humanity in Bedford, Massachusetts, renovate a farmhouse and build two new homes that will be made available for moderate-income families.

Lincoln Laboratory Hispanic and Latino Network

Through monthly meetings, mentoring, and other activities, the newly formed Hispanic and Latino Network (LLHLN) supports educational and professional development for its members, encourages involvement in community outreach activities, and fosters awareness of the Hispanic culture.

Mentorship Programs

Recognizing the importance strong mentorships have on improving employee development and retention, Lincoln Laboratory initiated four mentorship programs in 2011. The New Employee Guides program focuses on acquainting employees with their groups, divisions, or departments during their early months at the Laboratory. Staff can later choose to participate in more specialized mentoring programs:

- Early Career Mentoring provides a six-month, one-on-one mentorship to help technical and administrative professionals with early career development.
- Circle Mentoring uses small discussion groups led by experienced employees to address topics relevant to professional and career growth.
- By partnering a new assistant group leader with an experienced group leader, the New Assistant Group Leader Mentoring helps technical staff members transition into their new responsibilities.

OPPOSITE: The Lincoln Laboratory Technical Women's Network organized a multi-station "science fair" as the December Science on Saturday event. Shown here are many of the volunteers from across the Laboratory who made this event a successful experience for local children.

University Programs

MIT Student Programs

Undergraduate Research Opportunities Program (UROP)

In 2011, ten undergraduates were hired in the summer as part of the MIT Undergraduate Research Opportunities Program, which allows students to participate in every aspect of onsite research. Students develop research plans, write proposals, perform experiments, analyze data, and present research results.

MIT VI-A Master of Engineering Thesis Program

Six MIT students in the VI-A Master of Engineering Thesis Program were hired in 2011 (double the typical annual number of VI-A students) to work with a Laboratory mentor while gaining experience in testing, design, development, research, and programming. Students in the VI-A program spend two summers as paid interns, participating in projects related to their fields. Then, the students are paid as research assistants while developing their master of engineering theses under the supervision of both Laboratory engineers and MIT faculty.

Collaboration with the MIT Department of Aeronautics and Astronautics

Students from two courses in the MIT Department of Aeronautics and Astronautics built an unmanned aircraft that will carry a Lincoln Laboratory payload for measurement of ground-based antenna patterns. The two-semester project required students to design, construct, and flight test the vehicle. On the left is the first prototype of the students' design, and on the right is the final vehicle. Staff from the Laboratory's Tactical Defense Systems Group provided design guidance and test-range support while acting as the "customer" for the aircraft. This project afforded students a real-world experience of developing a product to meet customer specifications. After payload integration, the Laboratory will demonstrate the system's operational capability in 2011.

Other Student Programs

Summer Research Program

The Laboratory hires about 100 students from top universities every summer for internships in technical groups. Students gain hands-on experience in a leading-edge research environment while contributing to projects that complement their courses of study.

University Cooperative Education Students

In January 2011, twenty students from MIT, Northeastern University, and other area colleges joined the Laboratory to work part time during the school year and full time in the summer. Highly qualified students selected as co-ops become significant contributors to technical project teams. In July, twenty to thirty additional co-ops were hired for the summer.

Graduate Fellowship Program

In 2010–2011, seven students were awarded grants through this program that offers graduate fellowships to science and engineering students pursuing MS or PhD degrees at partner universities. Funds support a Fellow's stipend, supplement an assistantship, or subsidize other direct research expenses.

WPI Major Qualifying Project Program

In 2011, ten students were accepted as Laboratory interns under the Worcester Polytechnic Institute's Major Qualifying Project Program, which requires students to complete an undergraduate project equivalent to a senior thesis. The program allows students to demonstrate the application of skills, methods, and knowledge to problems typical of those encountered in industry.

Undergraduate Diversity Awards

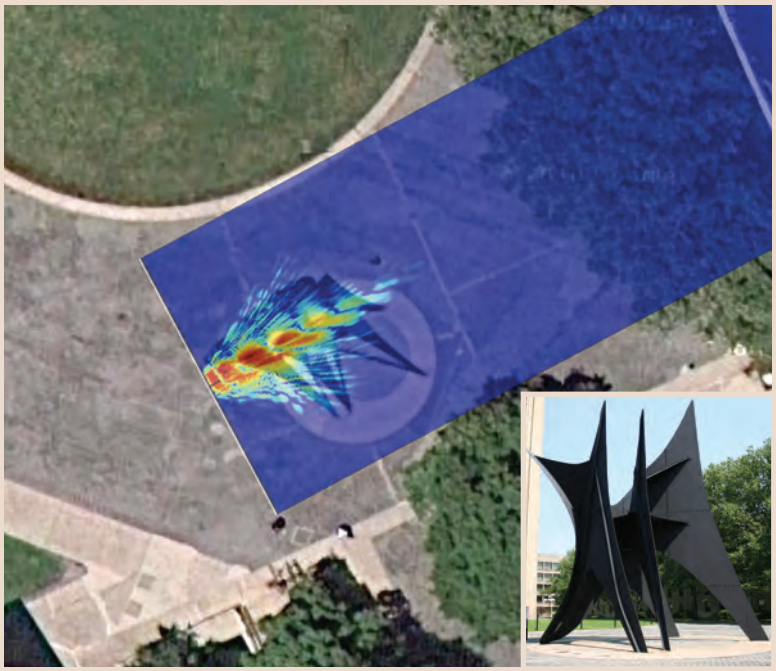
Lincoln Laboratory established the Undergraduate Diversity Awards to expand opportunities for women and minorities pursuing bachelor's degrees in engineering and science at eleven participating colleges. The award, as determined by the recipient's college, is typically in the form of tuition assistance, support for technical paper presentations, or funds for independent research projects.

MIT Student Programs

BUILD A SMALL RADAR COURSE

Lincoln Laboratory technical staff conducted a three-week course at MIT during the 2011 Independent Activity Period (IAP) in January. The goal of "Build a Small Radar System Capable of Sensing Range, Doppler, and Synthetic Aperture Radar Imaging" was to generate student interest in topics such as applied electromagnetics and signal processing through the construction and demonstration of a short-range radar sensor. Using Laboratory-designed radar kits, teams of students took the knowledge from the course lectures and built radar systems capable of measuring the speed of a passing car, plotting the range of moving targets, and imaging a scene.

The final activity for the class was a contest to form the most detailed synthetic aperture radar (SAR) image of an MIT campus scene by using the radar system built during the course. The team of Paresh Malalur, Nevada Sanchez, and Tony Hyun Kim used their system to form an image of a sculpture (see figure to the right). The team's "trophy," a coffee can mounted on a wooden base, pays homage to the coffee cans supplied in the radar kits as rudimentary transmit and receive antennas.



Alexander Calder, La Grande Voile, 1968. Photograph courtesy of MIT List Visual Arts Center.

This SAR image of the painted steel statue La Grande Voile (The Big Sail, inset) at MIT was the winning entry in the "Build a Small Radar" course. The image was collected by a radar that was built from coffee cans and that plugs into a laptop audio input.

Various "cantenna" radar systems are shown with their student designers. Dr. Eric Evans (standing far left) presented the trophy at the final session of the IAP radar course taught by Jonathan Williams (back row, third from left), Dr. Gregory Charvat (back row, fifth from left), and Drs. Alan Fenn, Stephen Kogon, and Jeffrey Herd (not pictured). Dr. Evans, along with Dr. Marc Bernstein, Associate Director, and Dr. Robert Shin, Head, ISR and Tactical Systems Division, judged the SAR imaging contest.

Technical Education and Workshops

Technical Education for Staff

Lincoln Laboratory offers a variety of educational opportunities for its staff. Courses for employees broaden technical knowledge and skills, and acquaint new staff members with the Laboratory's advanced technology and its technical themes. Through the Graduate Education Programs, staff members are encouraged to pursue advanced degrees. The Technology Office coordinates a series of seminars in which invited lecturers discuss results and implications of their innovative research or offer insights on new technologies.

Graduate Education

Lincoln Scholars Program

Currently, 27 technical staff members are enrolled in the Lincoln Scholars Program, a competitive program for which technical staff are eligible to apply and under which participants are funded by the Laboratory for full-time pursuit of an advanced degree at MIT or another local university. Lincoln Scholars contribute to the Laboratory under terms arranged with the Graduate Education Committee and work at the Laboratory during summer breaks. Over the past 18 months, one staff member earned a doctorate and eleven earned master's degrees through the program.

Distance Learning

Two distance learning programs coordinated by the Graduate Education Committee allow technical staff to earn advanced degrees while continuing to work full time at the Laboratory: the Master of Science in Information Technology–Software Engineering offered by Carnegie Mellon University and the Master of Professional Studies in Information Sciences offered by Pennsylvania State University College of Information Sciences and Technology. Currently, four people are enrolled in the Carnegie Mellon program and three in the Penn State program.

2010–2011 In-house Technical Courses

- Introduction to Algorithms
- Pattern Classification and Machine Learning
- Introduction to Radar Systems, Part II
- Introduction to Robotic Systems
- Decision Making Under Uncertainty

Lincoln Scholars Profile

PETER GROSSMANN: SEEKING LOW-POWER SOLUTIONS

Peter Grossmann is developing ultralow-voltage field-programmable gate arrays (FPGAs) that operate on the limited power budgets of ultralow-power systems. In building digital circuitry, the performance versus power trade-off is a central consideration: is achieving high performance or conserving power most important for the system? For many applications, for example, man-portable military sensors, wireless communication devices, or hearing aids, the small size of the device and the likelihood that it will be used in places with limited access to power-recharging demand energy saving. "I'm trying to give extremely power-starved systems the chance to consider FPGAs for the first time," he says.

Grossmann is conducting his research while studying full time for a PhD in computer engineering at Northeastern University. The Lincoln Scholars program is enabling his two pursuits. During the academic year, he is a graduate student performing his thesis research at the Laboratory; during semester and summer breaks, he is a contributing member of the Electro-optical Materials and Devices Group.

"This program makes it easier to think about how to make research practical and applicable. You can see things in a programmatic and goal-oriented way. It's not research just for research's sake," says Grossmann, who added that collaboration across groups in the Advanced Technology Division adds another dimension to his research: a sense of a larger design community that can take advantage of and also add to his work.

Technology Office Seminar Series

The goals of the series are to promote strong collaboration and inspire new ideas. Highlights from the 2011 series include

- Harnessing Information Fusion in Networks, Prof. Devavrat Shah, Department of Electrical Engineering and Computer Science, MIT
- Rapid Prototyping Tools: Adversarial Game Changer? Dr. Andrew "Zoz" Brooks, Co-host of the Discovery Channel's "Prototype This!"
- Fixing the Beating Heart: Ultrasound Image Processing for Robotic Cardiac Surgery, Prof. Robert D. Howe, Harvard School of Engineering and Applied Sciences
- Task Planning for Sensor-Based Multi-UAV Persistent ISR in Uncertain Environments, MIT Professor Jonathan How and Dan Levine, PhD
- High-Throughput Neurotechnology, Prof. Mehmet Yanik, Research Laboratory of Electronics at MIT

MILITARY FELLOWS PROGRAM

Laboratory Awards Fellowships for Military Officers

Lincoln Laboratory supports graduate education by awarding fellowships to military officers who are fulfilling requirements either for programs at senior professional military schools or for advanced degrees at MIT. During the academic year, fellows conduct research at the Laboratory for approximately two days a week and spend the remainder of the week on academic work at the MIT campus. Currently, U.S. Air Force, Army, and Navy officers are participating in the program.

LEFT: Lieutenant Colonel Scott Jackson, U.S. Army, presented a special seminar on the military application of biometric data in Iraq in 2009. LTC Jackson is assigned to the Chemical and Biological Defense Systems Group through the Army War College Senior Service Chaplain Forensics Fellowship Program.

BELOW: Lieutenant Colonel Thomas Schwab, U.S. Army, is working in the Cyber System Assessments Group. Under the Army's Training With Industry program, he is exploring cyber security issues.

LEFT: Lincoln Laboratory sponsors advanced education for graduates of the U.S. military academies. Front to back are 2nd Lt Kyle Smith, U.S. Air Force (USAF); ENS Zachary Bunting, U.S. Navy; 2nd Lt Alexander Horrell, USAF; and 2nd Lt Dylan Asmar, USAF. The four officers are master's-degree candidates at MIT and are performing their thesis research at the Laboratory.

Hosted Workshops and Courses

The range of workshops and seminars hosted by Lincoln Laboratory shows the breadth of research that the Laboratory shares with the technical and defense communities. The workshops address technology developments in long-standing program areas, such as air vehicle survivability and ballistic missile defense, and in its newer areas of research, such as homeland protection and cyber security.

Many workshops bring in guest speakers from the defense community, industry, and academia to add their perspectives on the application of advanced technology to their fields. These events provide valuable exchanges of ideas and insights into the direction for future research. Most workshops draw about 300 attendees. The exception is the Defense Technology Seminar, a week-long program of seminars and tours offered to approximately 60 to 70 invited guests from the military and government agencies.

Lincoln Laboratory also hosts a number of multi-day courses for user communities with which the Laboratory interacts. Courses for invited military officers and Department of Defense civilians enhance understanding of current research and the systems developed at the Laboratory, and are part of the Laboratory's mission to extend scientific knowledge. Technical staff also present courses at the Naval War College, Newport, Rhode Island; each semester, one course is scheduled, and the topics vary to address the college's needs.

2010–2011 Schedule

SEPTEMBER 2010

15–16 High Performance Embedded Computing Workshop

OCTOBER

19–21 Intelligence, Surveillance, and Reconnaissance Workshop

21–22 Anti-tamper Policy, Technology and Application Course

JANUARY 2011

12–13 (will repeat throughout the year) Anti-tamper Policy, Technology and Application Course

MARCH 2011

14–17 Homeland Protection Workshop Series

27 March–April 1 Defense Technology Seminar

APRIL 2011

26–28 Introduction to Intelligence, Surveillance, and Reconnaissance Course

MAY 2011

3–5 Space Control Conference

10–12 Air Vehicle Survivability Workshop

17–19 Ballistic Missile Defense Joint Advisory Committee Seminar

24–26 Networking and Communications Course

JUNE 2011

7–8 Lincoln Laboratory Communications Conference

14–16 Introduction to Radar Systems Course

JULY 2011

12–14 Cyber and Netcentric Workshop

SEPTEMBER 2011

20–22 High Performance Embedded Computing Workshop

This year marked the fifteenth annual Defense Technology Seminar at Lincoln Laboratory. Attendees included military officers and Department of Defense civilians. The seminar focused on the application of advanced electronics technology to critical surface, air, and space military challenges. A number of distinguished guest speakers offered insights on current national security issues.

Awards and Recognition

2011 IEEE Fellow

Dr. Mohamed D. Abouzahra, for "leadership in the development of passive planar microwave components and in planar microwave circuits."

2011 IEEE Microwave Theory and Techniques Society Outstanding Young Engineer Award

Dr. Jeremy B. Muldavin, for outstanding early-career contributions to the microwave profession.

2010 IEEE Signal Processing Society Best Paper Award

Dr. Steven T. Smith, for "Statistical Resolution Limits and the Complexified Cramér–Rao Bound," published in *Transactions on Signal Processing*.

2010 MIT Lincoln Laboratory Technical Excellence Awards

Dr. David J. Ebel, for his nationally recognized leadership in systems analysis to support the Department of Defense and for his use of detailed modeling, test data analysis, and a broad system perspective to provide superb analysis for air vehicle survivability, electronic warfare, and intelligence, surveillance, and reconnaissance systems.

Dr. William D. Ross, for critical contributions in the development of advanced imaging systems with applications in wide-area persistent surveillance, remote sensing, and homeland security, and in the development of enabling video sensor, processing, and data exploitation technologies.

MDA Director's Pinnacle Award

David P. Conrad, presented by Lieutenant General Patrick J. O'Reilly, MDA Director, "in recognition of significant accomplishments and contributions to the Missile Defense Agency."

The Airborne Ladar Imaging Research Testbed (ALIRT) team received the National Geospatial-Intelligence Agency's (NGA) 2011 GEOINT Analyst Award for terrain-mapping support to U.S. efforts in Afghanistan. Pictured left to right are Robert Shin, Head of the ISR and Tactical Systems Division; Richard Heinrichs, Leader of the Active Optical Systems Group; Richard Coveno; Christopher Reichert; Ross Anderson; Dale Fried; Brandon Call; Robert Knowlton, ALIRT program manager; and Ted Cope, director of geospatial intelligence (GEOINT) research at the NGA, who presented the award to the team.

2011 National Geospatial-Intelligence Agency's GEOINT Analyst Award

The ALIRT (Airborne Ladar Imaging Research Testbed) team, for "distinguishing itself in the wide-area mapping mission by providing high-resolution terrain data in Afghanistan to support the warfighter."

American Institute of Aeronautics and Astronautics (AIAA) Associate Fellow

Dr. Eric D. Evans, for outstanding contributions to the arts, sciences, or technology of aeronautics or astronautics.

2010 MIT Lincoln Laboratory Best Paper Award

Dr. Thomas F. Quatieri and **Tianyu T. Wang**, for their paper "High-Pitch Formant Estimation by Exploiting Temporal Change of Pitch," published in the *IEEE Transactions on Audio, Speech, and Language Processing*.

2010 MIT Lincoln Laboratory Best Invention Award

Dr. Robert K. Reich and **Harry R. Clark Jr.**, for the invention "Liquid Crystal Thermal Imagers," for which a U.S. patent has been filed.

2010 Tri-Services Radar Symposium Best Paper Award

Dr. Gregory L. Charvat and **John E. Peabody** of the Aerospace Sensor Technology Group, and Dr. Tyler S. Ralston, an MIT affiliate, for their paper, "A Through-Wall Real-Time MIMO Radar Sensor for Use at Standoff Ranges."

2010 MIT Lincoln Laboratory Early Career Technical Achievement Awards (also see sidebar)

Nadya T. Bliss, for her work in parallel computing, computer architectures, and graph processing algorithms and her leadership in anomaly detection in graph-based data.

Dr. Timothy M. Hancock, for development of small-form-factor RF systems and hardware for high-data-rate communication systems and his leadership in hardware development for multiple-input, multiple-output communication systems.

IEEE Computer Society Meritorious Service Award

Dr. Jonathan C. Herzog, "for outstanding innovative service to the Computer Security Foundations Symposium as publications chair and electronic proceedings archive editor."

Chairmanship of the Air Force Scientific Advisory Board

Dr. Eliahu H. Niewood, appointed to a three-year term as chairman of the Air Force Scientific Advisory Board.

Digital Avionics Systems Conference Best Paper Awards

James P. Chryssanthacopoulos, **Tomas R. Elder**, **Dr. Mykel J. Kochenderfer**, **Charles E. Rose**, and **Kevin Shih**, Best of Session award for the paper "Position Validation Strategies using Partially Observable Markov Decision Processes."

Thomas B. Billingsley, **James P. Chryssanthacopoulos**, and **Dr. Mykel J. Kochenderfer**, Best of Session and Best of Track awards for the paper "Collision Avoidance for General Aviation."

Mikhail Rubnich and **Richard A. DeLaura**, Best of Session award for the paper "Initial Validation of a Convective Weather Avoidance Model (CWAM) in Departure Airspace."

Dr. Panayiotis C. Tzanos and **Lester R. Mayer IV**, Best of Session for the paper "Comparison of ASR-11 and ASR-9 Surveillance Radar Azimuth Error."

2010 FFRDC Employee of the Year for the AEHF Program at the Air Force's Space and Missile Systems Center

Dr. Raymond F. Warriner, for his significant work on the Advanced Extremely High Frequency satellite communications program.

2010 MIT Excellence Awards

Unsung Hero Award

Vincent J. Cerrati, **David R. Granchelli**, and **Charles F. Nickerson** (posthumously awarded)

Greening MIT Award

Facility Services Department Conservation Team—**Donald N. Holmes**, **Joseph Dolan**, **David E. Barnes**, **David A. DeMoura**, **Michael Fodiman**, **Paul B. Foster**, **Richard P. Gabriele**, **John D. Kiser**, **Martin J. Millerick**, **James E. Milligan**, **Richard C. Perling**, **Michael Rocha**, **Peter Santa Lucia**, **Dennis P. Weron**, and **Robert J. Young**.

The MIT Lincoln Laboratory Facility Services Department Conservation Team was honored with a Greening MIT Award. Pictured are (front row, left to right) Prof. W. Eric L. Grimson, Chancellor, MIT; Theresa Stone, Executive Vice President and Treasurer, MIT; Dave Kiser; David DeMoura; Michael Rocha; Robert Young; and Paul Foster; (second row, left to right) Dr. Eric Evans, Director, MIT Lincoln Laboratory; Dr. L. Rafael Reif, Provost, MIT; Peter Santa Lucia; Richard Gabriele; Richard Perling; and Michael Fodiman; (third row, left to right) Jay Dolan, Assistant Department Head, Facility Services; Martin Millerick; Dennis Weron; Donald Holmes, Department Head, Facility Services; and David Barnes. (Photograph by Graham Ramsay)

2010 Superior Security Rating

To Lincoln Laboratory's collateral security program from the U.S. Air Force 66th Air Base Wing Information Protection Office

IEEE Milestone in Electrical Engineering and Computing

The First Real-Time Speech Communication on Packet Networks (1974–1982), demonstrated over the ARPANet between MIT Lincoln Laboratory and the University of Southern California's Information Sciences Institute, was designated an IEEE Milestone by the IEEE History Committee. The Milestones "recognize technological innovation and excellence for the benefit of humanity."

U.S. Army Outstanding Civilian Service Medal

Dr. Kenneth M. Chadwick, for his service as the director of the U.S. Army Space and Missile Defense Command's Research and Analysis Center in the Department of Physics and Nuclear Engineering, for contributions to research and physics programs, and dedication to cadet development at the U.S. Military Academy, West Point.

2010 Joseph H. Keenan Award for innovation in Undergraduate Education

Dr. Todd A. Thorsen, for development of the course "Micro/Nano Engineering Laboratory," offered by the MIT Department of Mechanical Engineering. Prof. Thorsen was a co-recipient of this award with MIT professors Sang-Gook Kim, Carol Livermore, and Rohit Karnik.

2011 Air Traffic Management Seminar Best Paper Award

Dr. Mykel J. Kochenderfer, **James P. Chryssanthacopoulos**, and **Dr. Roland E. Weibel** for the paper "A New Approach for Designing Safer Collision Avoidance Systems," presented at the 9th USA/Europe Air Traffic Management R&D Seminar.

Chairmanship of the 2012 IEEE Kilby Medal Committee

Dr. Joseph P. Campbell, named chair of the IEEE Jack S. Kilby Signal Processing Medal Committee. This award is the highest award given by the IEEE Signal Processing Society.

2012 American Meteorological Society Fellow

Dr. Marilyn M. Wolfson, for her "outstanding contributions to the atmospheric or related oceanic or hydrologic sciences, or their applications."

NASA Group Achievement Award

Dr. Grant H. Stokes and **Dr. J. Scott Stuart**, for participation on NASA's Near Earth Objects Observation Program Team, which demonstrated "outstanding accomplishment in detection and tracking of the population of larger near Earth objects."

2011 Bike Week Commuter Challenge Awards

Lincoln Laboratory was recognized with two 2011 Massachusetts Commuter Challenge awards: a first place award for outstanding participation and corporate bicycle services in the division of organizations with 3,000 to 4,999 employees and a first place award for the team with the highest mileage accrued during the Bike Week Challenge.

Awards

EARLY CAREER TECHNICAL ACHIEVEMENT AWARD

In 2010, Lincoln Laboratory established the Early Career Technical Achievement Award to recognize individuals under the age of 35 who had made significant contributions both to Laboratory mission areas and to their fields. The first two recipients were Nadya T. Bliss, Assistant Group Leader in the Embedded and High Performance Computing Group, and Timothy M. Hancock, Assistant Group Leader in the Analog Device Technology Group.

Ms. Bliss was recognized for her work in parallel computing, computer architectures, and graph processing algorithms. She was a key contributor to the parallel MATLAB (pMATLAB) project, which resulted in a parallel programming toolkit that enables MATLAB developers to run their codes on grid computers with minimal changes while allowing orders of magnitude performance improvement. She was a co-inventor and principal architect of the pMapper automated mapping system, a powerful system for determining the optimal decomposition of parallel signal processing algorithms onto parallel computer architectures.

Dr. Hancock was recognized for his development of small-form-factor radio-frequency (RF) systems and hardware supporting high-data-rate communication systems. For two programs addressing RF communications links, he led the hardware development activity that resulted in successful deliveries to the sponsor. He also assisted in the delivery of the hardware for Volcano Acme, a multiple-input multiple-output, high-data-rate communication system. Dr. Hancock is active in the Institute for Electrical and Electronics Engineers (IEEE).

R&D 100 Awards

Four technologies developed at MIT Lincoln Laboratory were named 2011 recipients of R&D 100 Awards. Given annually by *R&D Magazine*, an international journal for research scientists and engineers, these awards recognize the 100 most technologically significant innovations introduced during the previous year. Recipients of R&D 100 Awards are chosen from hundreds of nominations by an independent panel of evaluators and the editors of *R&D Magazine*. The awardees represent a broad range of technologies developed by industrial enterprises, government laboratories, and university research facilities from around the world.

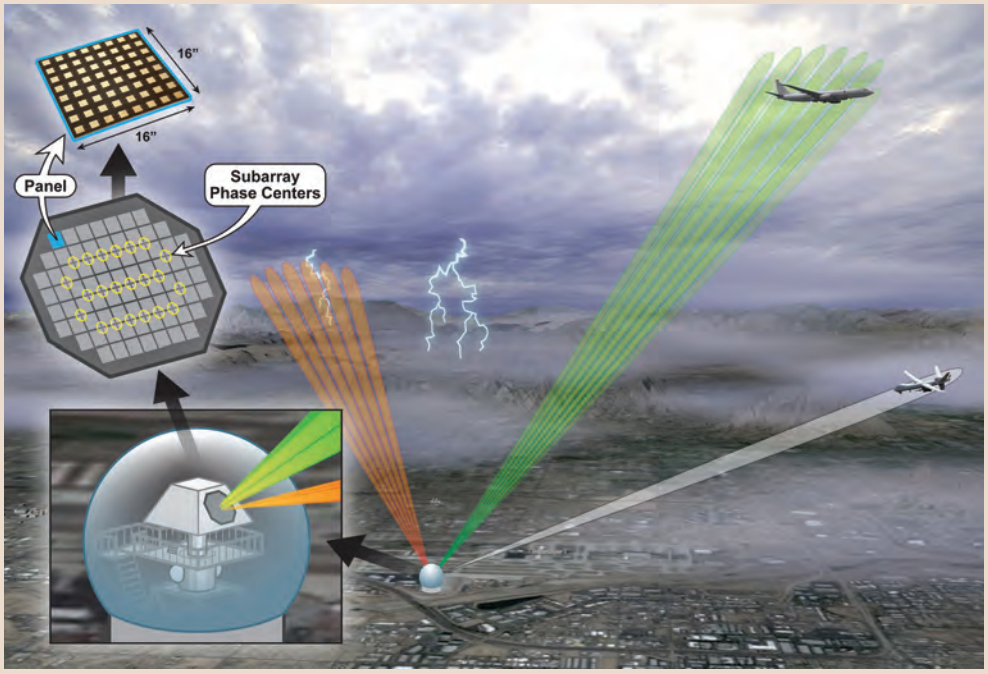
At the R&D 100 Awards banquet in Orlando, Florida, on 13 October, members of the teams that won 2011 awards accepted commemorative plaques. Pictured here are (back row, left to right) Christopher Reichert, Brandon Call, and Robert Knowlton of the Airborne Ladar Imaging Research Testbed (ALIRT) team; Marc Bernstein, Associate Director, Lincoln Laboratory; John Cho and Sean Duffy of the Multifunction Phased Array Radar (MPAR) Panel team; (front row, left to right) Edward Rutledge of the Parallel Vector Tile Optimizing Library team; Joseph Lacirignola and James Harper of the Pathogen Analyzer for Threatening Environmental Releases Bioaerosol Identification System team; Ross Anderson of the ALIRT team; Jeffrey Herd and Chris Weigand (from M/A-COM) of the MPAR Panel team.

Multifunction Phased Array Radar Panel

Panels of phased arrays exploit dual polarization and digital beamforming to provide efficient radar detection and tracking of aircraft and weather targets

TEAM: Dr. Jeffrey Herd (program manager), Glenn Brigham, Dr. John Cho, David Conway, Dr. Sean Duffy, Sean Tobin, and Dr. Mark Weber. Team members from M/A-COM Technology Solutions are Douglas Carlson, Christopher Weigand, and Daniel Curcio.

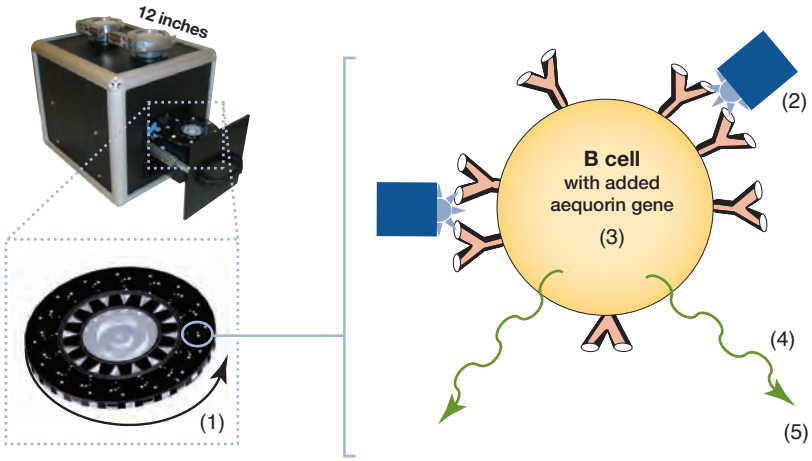
Selected for one of three 2011 Editor's Choice Awards



Pathogen Analyzer for Threatening Environmental Releases Bioaerosol Identification System

A highly sensitive sensor that uses genetically modified white blood cells to rapidly detect and identify pathogens and toxins

TEAM: Dr. James Harper, Joseph Lacirignola, and Richard Mathews led the development of the portable PANTHER prototype; Dr. Shaun Berry, Dr. Catherine Cabrera, Dr. John D'Angelo, Dr. Mark Hollis, Dr. Frances Nargi, John O'Fallon, Dr. Lalitha Parameswaran, Dr. Martha Petrovick, Dr. Todd Rider, Dr. Eric Schwoebel, Timothy Stephens, and Trina Vian made significant contributions to the underlying CANARY technology and sensor hardware.



Detection Process

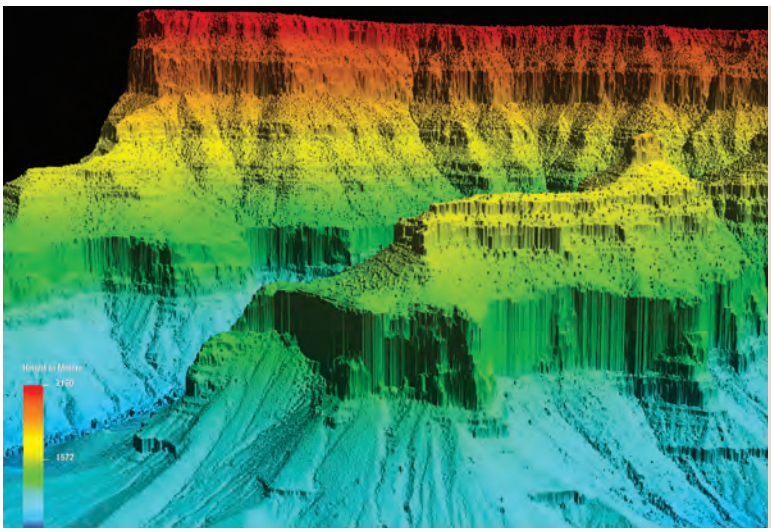
(1) Bioagent–containing aerosol is collected; disc is spun after collection to release B cells

(2) Pathogens crosslink antibodies

(3) Biochemical signal amplification releases Ca^{2+}

(4) Ca^{2+} prompts aequorin to emit photons

(5) Photons are detected by sensor



Airborne Ladar Imaging Research Testbed

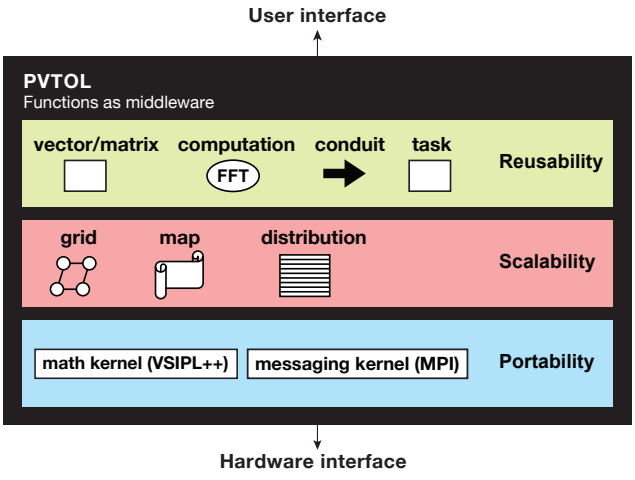
An airborne laser radar that rapidly collects high-resolution three-dimensional imagery of wide-area terrains

TEAM: Robert Knowlton (program manager), Joseph Adams, Ross Anderson, Leonas Bernotas, Kenneth Burkett, Brandon Call, Robert Carlson, David Ceddia, Vincent Cerrati, Paul Consalvo, Jack Duston, Robert Freehart, Dr. Dale Fried, Robert Hatch, Dr. Richard Heinrichs, Alex McIntosh, Joseph McLaughlin, Christopher McNeil, James Mooney, Michael O'Brien, Frank Perry, Brian Player, Ryan Poplin, Prem Ramaswami, Christopher Reichert, Dr. John Shelton, Tina Shih, Luke Skelly, Daniel Stremeckus, Paul Tirone, Alexandru Vasile, Berton Willard, Alexander Wilson, and Dr. John Zayhowski. In addition, the team was supported by pilots Robert Keller and Bryan Williams of Sunshine Aero Industries.

Parallel Vector Tile Optimizing Library

A real-time signal processing library that enables cross-platform portability of programs without sacrificing high performance

TEAM: James Daly (lead developer), Nadya Bliss, Robert Bond, Karen Eng, Ryan Haney, Hahn Kim, Dr. Jeremy Kepner, Scott Lacroix, Dr. Sanjeev Mohindra, Edward Rutledge, and Glenn Schrader.



60th Anniversary Celebration

In 2011, MIT Lincoln Laboratory celebrated its 60th anniversary. A committee drawn from across the Laboratory planned a year of events to celebrate the anniversary. These events were well-received and provided opportunities to share experiences and to learn more about our heritage of service to the nation. Our historical timeline display was updated and installed in key locations around the Laboratory. Additionally, all employees will receive a copy of the new Lincoln Laboratory history book that brings our story up to the present and illustrates our continued vitality and growth.

1951–2011
LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

10 APRIL AND 30 APRIL

MIT 150

Lincoln Laboratory connected with MIT's 150th anniversary celebration. At MIT's Next-Century Convocation, held on 10 April at the Boston Convention and Exhibition Center, the Laboratory mounted a large exhibit showcasing noteworthy technological programs. During the 30 April open house at campus, Laboratory engineers demonstrated robotics, voice transformation systems, speaker and language identification, and infrared cameras.

18 May

MFA GALA

At a gala at the Museum of Fine Arts Boston, more than 575 current and past employees, along with their guests, enjoyed the galleries, including the new Art of the Americas wing, a special exhibit of artist Dale Chihuly's blown-glass sculptures, dining, and dancing.

25 MAY

Recognition Day

Recognition Day honored Lincoln Laboratory's contributions to the nation. Among the speakers at the courtyard ceremony for employees and invited guests were MIT President Susan Hockfield; Ashton Carter, Deputy Secretary of Defense; and Zachary Lemnios, Assistant Secretary of Defense for Research and Engineering. The U.S. Air Force Band of Liberty and a vocal ensemble of Laboratory employees performed.

18 September

OPEN HOUSE

Employees and retirees brought family members to a day-long open house event featuring exhibits and interactive science demonstrations. Historical displays showcased some of the Laboratory's pioneering work in air defense, satellite communications, and advanced electronics. About 6000 people attended the open house event that was planned and run by many volunteers from all across the Laboratory. The Flight and Antenna Test Facility on Hanscom Air Force Base and the Lincoln Space Surveillance Complex at Millstone Hill in Westford, Massachusetts, were also open for tours and activities.

YEARLONG

Heritage Lecture Series

The Heritage Lectures, a monthly series tracing the evolution of the Laboratory, kicked off in February with Director Emeritus Walter Morrow giving an overview of Lincoln Laboratory's establishment and initial project, the Semi-Automatic Ground Environment air defense system. Subsequent talks recapped work in areas such as satellite communications, ballistic missile defense, and advanced electronics. Director Eric Evans wrapped up the series with a look at future challenges. Also looking toward the future were the Distinguished Lectures, a series on emerging trends in science and engineering given by innovators from industry.

EDUCATIONAL AND COMMUNITY OUTREACH 63

THIS PAGE: On their visit to Lincoln Laboratory, students in MIT's summer STEM program experiment with Hexbug's Nanos to learn how these tiny robots behave seemingly intelligently. For more on Robotics Outreach, see page 67.

Outreach

Community outreach programs, including those for STEM education, robotics, and charitable service and giving, are an important component of the Laboratory's mission and experienced much growth during the year.

The success of these programs reaffirms the commitment of the Laboratory community in motivating participation in science, technology, engineering, and math programs for K–12 students and supporting charitable organizations to help those in need. New efforts this year include the "Wow! That's Engineering!" event for girls, more robotics teams in a variety of age groups, and many new giving programs, including donations for homeless teens and walk-a-thons to raise funds for cystic fibrosis research and the care of cancer patients.

Educational Outreach

Science on Saturday

Lincoln Laboratory continued its popular Science on Saturday series of hands-on demonstrations for K–12 students. This year, the trend of sold-out shows continued, and more than 18 scientists and engineers volunteered as presenters, an increase of ten from last year. Demonstrations in 2011 included acoustics, how computers work, and robotics.

Classroom Presentations

Volunteers in the Classroom Presentations program visited more than 50 schools in the 2010–2011 school year. Many of these schools receive annual visits from Lincoln Laboratory scientists, gaining sustained opportunities to stress the importance of science, technology, engineering, and mathematics.

AFCEA International Program

In 2011, the Laboratory will hire three AFCEA (Armed Forces Communications and Electronics Association) interns from Massachusetts. The high-school students gain experience in a laboratory. Lincoln Laboratory also offers a picnic and a tour of the facilities to the AFCEA students in the area.

John D. O'Bryant School of Math and Science Partnership

Twice each year, students of John D. O'Bryant School of Mathematics and Science in Roxbury, Massachusetts, tour the Laboratory. In 2011, the students listened to Bryan Reid of the Optical Systems Engineering Group and Son-Ca Nguyen of the Engineering Analysis and Testing Group explain why they chose careers in engineering. This year marked the first year the O'Bryant School robotics team was assisted financially and educationally by Lincoln Laboratory.

Student Internships

This cooperative internship program provides two students from the Minuteman Career and Technical High School and one student from Shawsheen Technical Vocational High School with hands-on experience in a real-world setting.

LIFT^2

In 2011, one teacher held an internship at the Laboratory. The Leadership Initiatives for Teaching and Technology (LIFT^2) program offers middle- and high-school teachers internships in order to help them better prepare students for math- and science-related jobs in the 21st century, and to encourage high-school students to pursue careers in science, technology, engineering, and math.

Wow! That's Engineering!

One hundred girls in grades 6–8 tried different types of engineering through various activities at "Wow! That's Engineering!" hosted in March and July at Lincoln Laboratory by the Boston chapter of the Society of Women Engineers.

MIT Office of Engineering Outreach Progams (OEOP)

The MIT Department of Engineering's OEOP programs offer deserving students rigorous academic experiences that provide an understanding of how technical

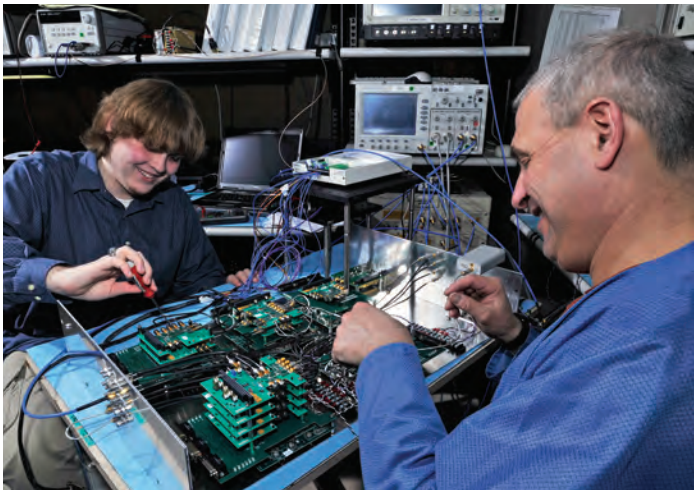
EDUCATIONAL OUTREACH BY THE NUMBERS

20
K–12 STEM programs

100+
Lincoln Laboratory scientists and engineers working with students

5,250
volunteer hours a year in STEM programs

10,000+
students participated in Lincoln Laboratory STEM programs



CLOCKWISE FROM TOP LEFT:
Todd Rider of the Chemical, Biological, and Nanoscale Technologies Group brings fossils to a middle school for an in-depth presentation; Cameron Houdlette, student intern from Shawsheen Technical Vocational High School, works with Barry Romkey in the Optical Communications Technology Group, learning the daily work of an engineer and technician; MSBP students and outreach volunteers play a "scientists versus students" softball game as part of their Laboratory experience; Jessica Holland of the Surveillance Systems Group helps children understand centrifugal force during a Science on Saturday presentation on Amusement Park Physics.

Educational Outreach Activities

LABORATORY INVOLVEMENT IN SCIENCE FAIRS

Massachusetts State Science and Engineering Fair

Held at MIT in May, the 2011 fair enjoyed the Laboratory's continued bronze sponsorship. Lincoln Laboratory's involvement as judges nearly doubled since 2010. The 16 staff members serving as judges for this year's science fair were David Brown, Miriam Cha, Shourov Chatterji, Kenneth Cole, Phillip Evans, Caroline Fernandes, Claude French, Caroline Lamb, Christopher Lloyd, Bernard Malouin, Scott Philips, Alex Pina, Todd Rider, Zachary Weber, Erica Wiken, and Jung Yoon.

Cambridge Science Festival

Robotics Outreach at Lincoln Laboratory manned three booths at the annual nine-day event. Each booth offered hands-on robotic challenges for different age groups. Masahiro Arakawa of the Embedded and High Performance Computing Group reprised a Science on Saturday demonstration called "How Computers Work" at the Cambridge Public Library as part of this city-wide event.

Lexington High School Science and Engineering Fair

In February 2011, Laboratory scientists Grant Stokes, Brie Howley, Zachary Weber, Daniel Weidman, Christy Cull, Evan Cull, and Mykel Kochenderfer served as judges for the Lexington High School Science and Engineering Fair.

Science on the Mall

The USA Science and Engineering Festival, the country's first national science festival, was held in Washington, D.C., in late 2010. Lincoln Laboratory was one of 850 organizations participating in the festival. Visitors to the Laboratory's booth played robot soccer with robots built from kits utilizing Lego Mindstorms and Tetrix Education parts.

concepts relate to everyday life. OEOP programs encourage the pursuit of technical careers and provide a hands-on curriculum in a challenging learning environment. Lincoln Laboratory plays a part in four OEOP programs:

MIT Science of Baseball Program (MSBP)

This summer program directs enthusiasm for baseball into excitement for the math and science behind the game. The Laboratory sponsors a student, provides presentations and tours of facilities, and hosts a hotly anticipated "scientists versus students" softball game. Heriberto Garcia of the BMDS Integration Group and Rodolfo Cuevas of the Systems and Architectures Group gave presentations on their career choices.

Science, Technology, Engineering, and Mathematics (STEM) Program

STEM helps middle-school students develop problem-solving skills needed for advanced math and science classes in high school. The Laboratory sponsors a robotics demonstration and course, provides a tour of the facilities, and presents a science demonstration. Hayley Reynolds of the Weather Sensing Group and Eric Larrieux of the Sensor Technology and System Applications Group discussed their career choices.

Saturday Engineering and Enrichment Discovery (SEED) Academy

In this technical career-exploration program for high-school students, Lincoln Laboratory sponsored an aeronautics/astrophysics course and provided tours of Laboratory facilities. Christ Richmond of the Advanced Sensor Techniques Group and Virginia Goodwin of the Surveillance Systems Group gave presentations on why they entered engineering.

Minority Introduction to Engineering and Science (MITES) Program

This six-week summer program for top high-school students in the nation stresses the value of pursuing technical degrees and develops the skills to achieve success. The Laboratory sponsors two MITES students. Michelle Clark of the Chemical, Biological, and Nanoscale Technologies Group, and David Freeman of the Optical Systems Engineering Group gave presentations about their career choices. The 75 MITES students toured the Laboratory's specialized facilities.

EDUCATIONAL OUTREACH PROFILE

Damaris Toepel: Role model for young women

Damaris Toepel, a staff member working in the Engineering Analysis and Testing Group, assists in analysis for the assembly, test, and integration of two flight module telescopes for the Revelio program. Even though she is fairly new to the Laboratory, she has represented the Laboratory in outreach programs and engineering groups for minorities.

Ms. Toepel coordinated the "Wow! That's Engineering!" educational event. The event consisted of 100 middle-school girls mentored by more than 50 female technical staff members from at least eight different technical organizations. She says, "Targeting girls in middle school is so crucial. It's when many girls lose their enthusiasm for science or feel that science and technology fields are not for them. We're taking this opportunity to show them that engineering can be exciting and that it is a viable career choice for women." She adds, "Sixth, seventh, and eighth graders are really concerned with what their peers think of them and what their peers are doing, so being able to do these activities themselves is critical." Ms. Toepel would like to get more people involved in outreach since "it's important to relay the exciting work we do as engineers to young people."

Diversity is also important for Ms. Toepel: "When I was in college, I was involved in diversity organizations, like the Society of Hispanic Professional Engineers, Society of Mexican-American Engineers and Scientists, and the Society of Women Engineers. Because the Laboratory places a priority on its affiliation with these organizations, I'm starting to get involved with them again as a representative of Lincoln Laboratory. I enjoy mentoring, participating in outreach events, and helping out with college recruiting."

Robotics Outreach

FIRST Robotics Competitions

Members of the Robotics Outreach at Lincoln Laboratory (ROLL) committee serve as coaches for 17 For Inspiration and Recognition of Science and Technology (FIRST) robotics teams.

In late 2010, Lincoln Laboratory staff coached 12 robotics teams (2 high-school teams, 9 middle-school and older elementary-school teams, and 1 younger elementary-school team) and mentored 5 teams affiliated with local schools. Newly established Roboworkshops allowed children to hone their programming skills after the competition season.

Boy Scout Robotics

New to robotics outreach activities in 2011 is the Laboratory's involvement in the Boy Scout Robotics Merit Badge. Lincoln Laboratory volunteers helped to provide twelve robotic kits used during a "Robot Block Party" at the Boston Museum of Science for a

BELOW: Robotics teams prepare for competition at FIRST events. Team Robover (left) plans its robot's course; Team Insane Robot Posse (center and right) set up for the challenge course.

ROBOTICS BY THE NUMBERS

2
teams won awards at the U.S. FIRST World Championship

3
new programs in the robotics outreach program

8
new teams since last year

17
robotics teams coached by Laboratory volunteers

23
Laboratory volunteers assisting robotics teams

32
children returning to the Lincoln Laboratory robotics program

80+
children participating in Lincoln Laboratory teams

Boy Scouts–only event during National Robotics Week. Laboratory volunteers served as merit badge counselors for this event.

SeaPerch Derby

The SeaPerch Derby challenges elementary-, middle-, and high-school students to construct a simple, remotely operated, underwater vehicle from PVC pipe and other materials. The SeaPerch program teaches students basic skills in ship and submarine design, and encourages them to explore naval architecture and marine and ocean engineering concepts. This competition has separate categories for middle- and high-school entrants in three events: general design and craftsmanship, maneuvering, and a simulated sea rescue. The inaugural Army-Navy-Air Force regional competition was designed to promote excellence and interest in science, technology, engineering, and mathematics education. Approximately 65 students participated (see sidebar below).

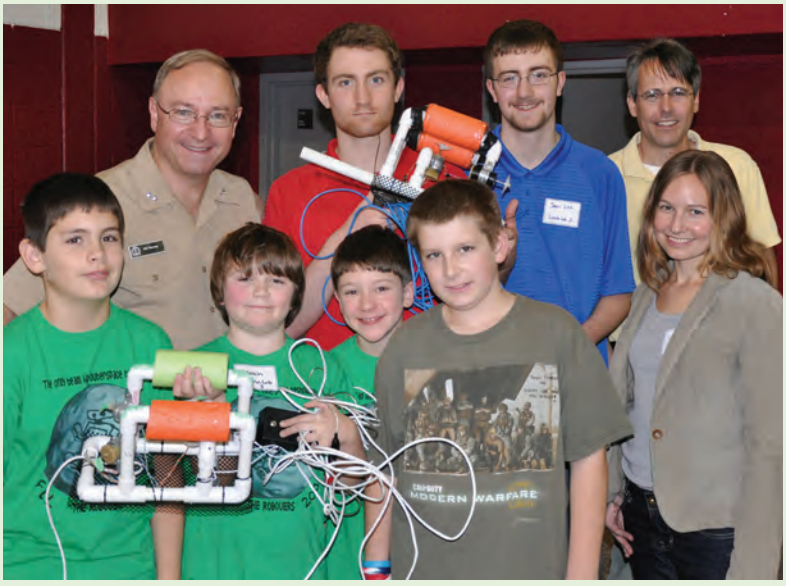
Robotics Outreach Profile

BEN LIST: ROLLING INTO ENGINEERING

Ben List joined Lincoln Laboratory's robotics outreach program (ROLL) during his junior year of high school. Even in its rookie year, Ben's team (MITiBots) performed well enough to compete in the International Championship Tournament. In his senior year, Ben served as mechanical supervisor on the team, which has returned to the championships three years in a row.

When asked what he liked about the robotics program, he replied, "In school, you learn theory and how things work, but what I like about robotics is that I got to apply my knowledge. When I was building the robot, I was still learning, but it was up to me to connect the dots between what I knew from school and what I gained in practice about how to make it work myself."

Not only was Ben's experience in robotics helpful in gaining skills, but also in determining his college career. "Being in the Lincoln robotics program definitely helped me solidify my choice for my college major," he said. "I was considering a few other areas of study, but my background in robotics made it easier to make a final choice, and be confident that I was making the right choice." Ben, now a freshman at Worcester Polytechnic Institute, plans to study mechanical engineering.



Ben List, back row, second from left, with his younger brother, Sam, second from right, made up one of the two student teams participating in the SeaPerch Derby at New Bedford High School. Jonathan Williams, back right, of the Advanced Capabilities and Systems Group and Jennifer Eisenman, front right, of the Air Defense Techniques Group volunteered to mentor the teams. The teams are pictured here with RADM Phil Wisecup, back left, current Naval Inspector General and former president of the U.S. Naval War College, the sponsor of the derby.

Community Giving

New Volunteerism in 2011

Lincoln Laboratory employees volunteered to help raise funds for the Lowell General Hospital's TeamWalk for CancerCare and Great Strides for Cystic Fibrosis. Generous Laboratory employees also donated to Massachusetts Coalition for the Homeless, Burlington Food Pantry, and Catie's Closet for homeless teens, and aided Bikes Not Bombs in disassembling bikes for shipment to Ghana, Tanzania, Guatemala, and Nevis Island.

Troop Support

Lincoln Laboratory's Troop Support Program has sent more than 200 care packages to U.S. troops every year since 2007. Care packages contain needed toiletries, snacks, and books or CDs, plus a letter from Lincoln Laboratory. In late 2010, Troop Support held a holiday event called "Crafting for a Cause," which raised an extra $1400 for special holiday care packages for U.S. troops in Afghanistan.

ABOVE: Volunteers prepare boxes for mailing to troops in Afghanistan. From left, Carmen Caballero, Mike Chaplin, Dave Myers, and Joanne Knoll, who manages the troop support program.

Multiple Sclerosis Bike & Hike the Berkshires

The 15-member team of the Greater New England Chapter of the National Multiple Sclerosis Society raised more than $9,000, ranking them the second leading corporate fundraiser for this event.

Alzheimer's Association Memory Walk

Eighteen team members supporting the Massachusetts/New Hampshire Chapter of the Alzheimer's Association raised more than $17,000 and was the third highest fundraising team.

Coats for Kids Drive

A total of 435 gently used warm coats and jackets were donated for needy children in the area through this program run by Anton's Cleaners.

Hannah's Socks Sock Drive

Because of this program aimed at the homeless, 565 socks, undergarments, gloves, and warm hats were gratefully received by the Veterans Administration Hospital in Bedford, Massachusetts.

COMMUNITY GIVING BY THE NUMBERS

6
new giving programs held in 2011

20
charities benefited by Lincoln Laboratory's community giving programs

60
runners registered for the 5K Fun Run to support a veterans hospital

200
boxes of supplies and snacks shipped overseas to U.S. soldiers per year

435
coats collected in the Coats for Kids Drive

565
socks and warm items collected for the Hannah's Socks drive

9,031
dollars raised to help strike out multiple sclerosis

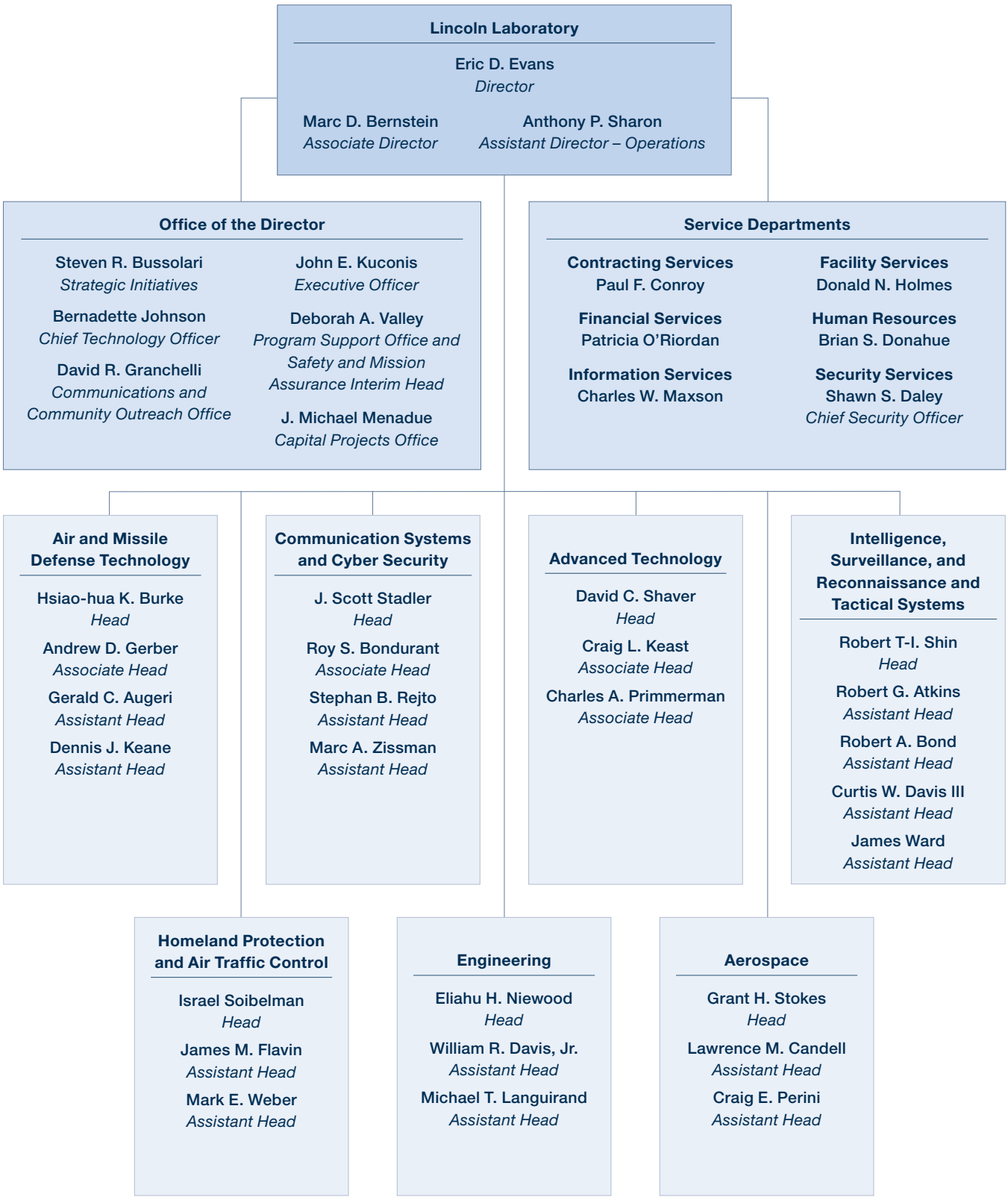
17,000+
dollars raised to fund research and help Alzheimer's patients


LINCOLN LABORATORY

ORGANIZATION AND GOVERNANCE 71

Laboratory Organization

MIT Lincoln Laboratory Organizational Chart



Governance

MIT

Office of the President
Dr. Susan Hockfield, President

Office of the Provost
Dr. L. Rafael Reif, Provost

Dr. Claude R. Canizares, Vice President for Research and Associate Provost

DoD Joint Advisory Committee
Annually reviews the Laboratory's proposal for programs to be undertaken in the subsequent fiscal year and five-year plan.

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Principal Deputy, Assistant Secretary of Defense for Research and Engineering

Dr. Regina E. Dugan
Director, Defense Advanced Research Projects Agency

Gen Bruce Carlson, USAF (Ret)
Director, National Reconnaissance Office

LTG Patrick J. O'Reilly
Director, Missile Defense Agency

Ms. Heidi Shyu
Acting Assistant Secretary of the Army for Acquisition, Logistics and Technology

Mr. Sean J. Stackley
Assistant Secretary of the Navy for Research, Development and Acquisition

Mr. David Van Buren
Acting Assistant Secretary of the Air Force for Acquisition

Maj Gen William N. McCasland
Commander, Air Force Research Laboratory, Joint Advisory Committee Executive Group—Chair

MIT Lincoln Laboratory Advisory Board
Appointed by the MIT President and reports to the Provost. The Advisory Board meets twice a year to review the direction of Laboratory programs.

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Former Chairman and CEO of Northrop Grumman

Prof. Angela M. Belcher
Germeshausen Professor of Materials Science and Engineering, Massachusetts Institute of Technology

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Co-chairman and Co-CEO, Stone Key Partners; Former member, President's Foreign Intelligence Advisory Board

VADM David E. Frost, USN (Ret)
President, Frost & Associates, Inc.; Former Deputy Commander, U.S. Space Command

Dr. Arthur Gelb
President, Four Sigma Corporation; Former Chairman and CEO of The Analytic Sciences Corporation

ADM Edmund P. Giambastiani Jr., USN (Ret)
Former Vice-Chairman of the Joint Chiefs of Staff

Prof. Daniel E. Hastings
Dean of Undergraduate Education, Massachusetts Institute of Technology; Former Chief Scientist of the Air Force

Dr. Miriam John
Vice President Emeritus of Sandia National Laboratories

Dr. Paul G. Kaminski
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Gen Lester L. Lyles, USAF (Ret)
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Prof. Hans Mark
The University of Texas at Austin; Former Secretary of the Air Force; Former Deputy Administrator of NASA

Prof. Jeffrey H. Shapiro
Julius A. Stratton Professor of Electrical Engineering, Massachusetts Institute of Technology

Mr. John P. Stenbit
Former Assistant Secretary of Defense (C3I); Former Executive Vice President, TRW

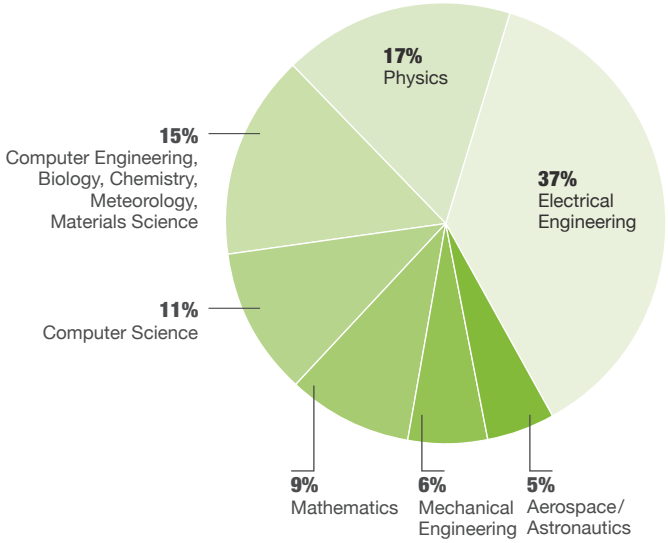
GEN Gordon R. Sullivan
President of the Association of the U.S. Army; Former Chief of Staff of the U.S. Army

Staff and Laboratory Programs

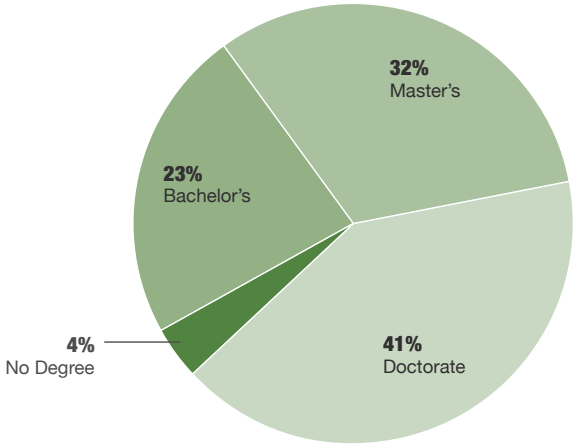
1,670	Professional Technical Staff
1,067	Support Personnel
392	Technical Support
584	Subcontractors
3,713	**Total Employees**

Composition of Professional Technical Staff

Academic Discipline

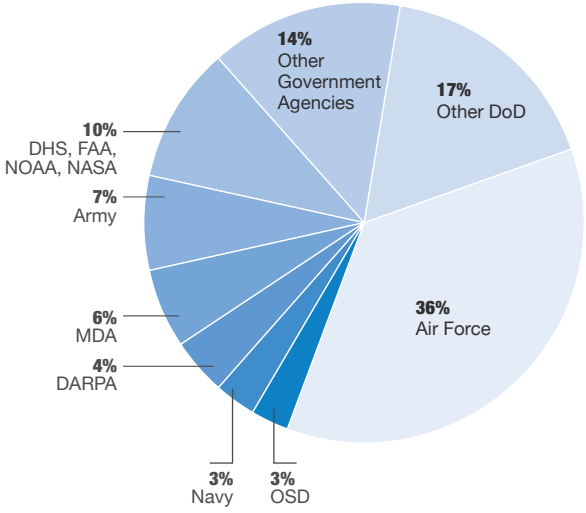


Academic Degree

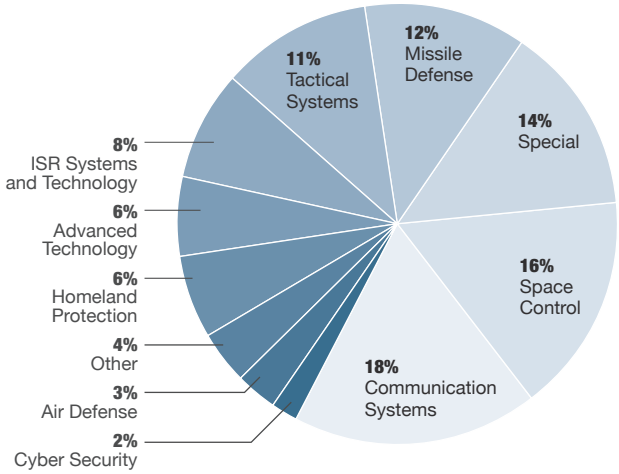


Breakdown of Laboratory Program Funding

Sponsor



Mission Area



Lincoln Space Surveillance Complex, Westford, Massachusetts

Reagan Test Site, Kwajalein Atoll, Marshall Islands