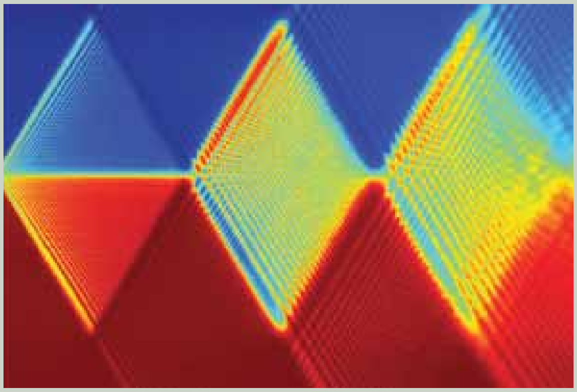
MIT LINCOLN LABORATORY

2009 ANNUAL REPORT



TECHNOLOGY IN SUPPORT OF NATIONAL SECURITY


Massachusetts Institute of Technology


MIT Lincoln Laboratory

MIT LINCOLN LABORATORY

2009

MISSION:

TECHNOLOGY IN SUPPORT OF NATIONAL SECURITY

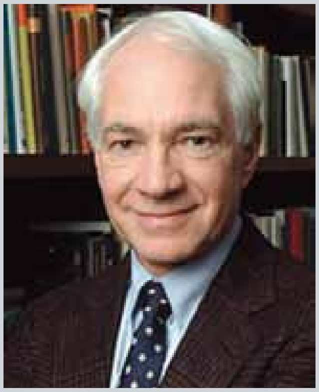
MIT Lincoln Laboratory employs some of the nation's best technical talent to support system and technology development for our national security needs. Principal core competencies are sensors, information extraction (signal processing and embedded computing), communications, and integrated sensing and decision support. Nearly all of the Lincoln Laboratory efforts are housed at the Hanscom Air Force Base complex 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 defense 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 for which the government cannot rely on in-house or private-sector 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 58 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.

Massachusetts Institute of Technology


Dr. Susan Hockfield
President


Dr. L. Rafael Reif
Provost


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

MIT Lincoln Laboratory


Dr. Eric D. Evans
Director


Dr. Marc D. Bernstein
Associate Director


Mr. Anthony P. Sharon
Assistant Director – Operations

LETTER from the Director of MIT Lincoln Laboratory

MIT Lincoln Laboratory continues to serve the nation by developing advanced technology in support of national security. As new needs emerge, the Laboratory continues to evolve its mission areas and programs. This year, new efforts were started to develop systems and technology for cyber network protection, homeland air defense, counterterrorism, and protection of U.S. space assets. The Laboratory has made significant progress toward implementing new open-system architectures for net-centric operations across multiple mission areas. Work has been initiated on a lunar laser communication link for a NASA satellite program. New counter–improvised explosive device (IED) technology has been rapidly developed and transitioned to support soldiers' needs in Iraq and Afghanistan. Through these and other programs, the Laboratory continues to focus on early hardware and software prototyping, real-world demonstration, and technology transition to industry and system users.

Over the past year, two Assistant Directors reached the age when, by Laboratory policy, they step aside from their senior management roles. I would like to thank Dr. Antonio Pensa and Mr. Lee Upton for their many years of service in the Director's Office. They both have made significant technical contributions over their decades of leadership at the Laboratory. I would also like to welcome Dr. Marc Bernstein, Dr. Steven Bussolari, and Dr. Bernadette Johnson to the Director's Office. Marc is now the Laboratory's Associate Director; Steve is on the Director's Office Staff for Strategic Initiatives; and Bernadette is the Laboratory's Chief Technology Officer. All three are nationally recognized for their technical leadership. We also welcome Ms. Cheryl Overs as the new Department Head of our Financial Services Department. Cheryl brings to us significant experience from her past corporate roles.

This has been a busy year for system prototyping and demonstration. Laboratory work reaching major technical milestones this year includes:

- Deployment of the Corridor Integrated Weather System for continental U.S. coverage
- Deployment of a high-performance image processor for data interpretation in Iraq
- Completion of new system upgrades for the National Capital Region homeland air defense system
- Multiple demonstrations of network-centric sensor integration and decision support systems
- Development of a new data integration center for sensor measurements at the U.S. Reagan Test Site in the Republic of the Marshall Islands
- Demonstration of high-data-rate laser communication using high-efficiency, superconducting photon-counting detectors
- Continued development of an explosives detection system using ultraviolet-induced fluorescence

Our ongoing joint research initiatives with the MIT campus continue at an all-time high. A multiyear, integrated photonics collaboration has led to improved detectors for advanced communications systems. Initiatives in the robotics area have led to the demonstration of new autonomous vehicles for stressing defense needs. New collaborative research is developing in the cognitive and decision sciences. Our relationship with MIT is central to our culture and values.

The Lincoln Laboratory Community Outreach program has been expanding. The K–12 educational outreach efforts are centered on classroom seminars at local schools and Science on Saturday programs for students. The Laboratory has also sponsored and mentored robotics teams as a part of the For Inspiration and Recognition of Science and Technology (FIRST) program. Last year, Laboratory-led FIRST teams did very well at state and national competitions.

We encourage you to review this annual report for the latest update of the Laboratory's research and development programs. We are looking forward to the future as we continue to focus on technical excellence, innovation, and integrity.

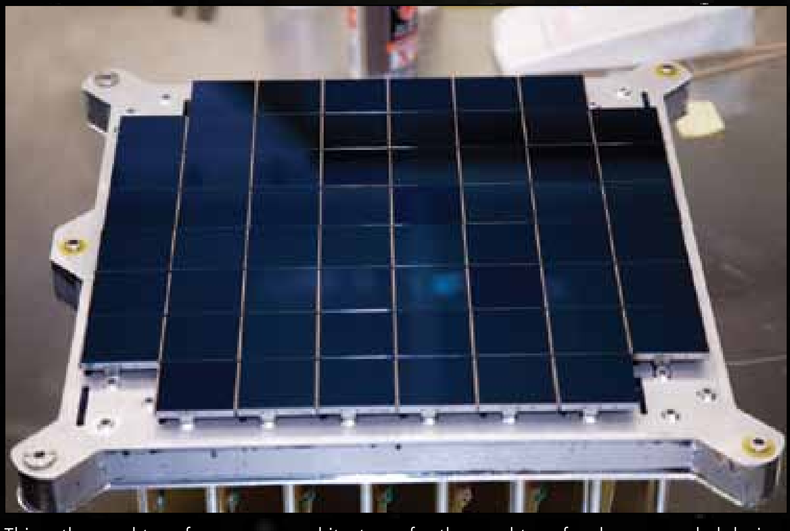
Sincerely,

Eric D. Evans
Director

Lincoln Laboratory Strategic Directions

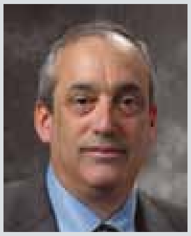
Strategic directions for Lincoln Laboratory are based on a Director's Office and senior management update of the Laboratory's strategic plan and a review of national-level studies, such as the National Defense Strategy, the Quadrennial Defense Review, and recent Defense Science Board recommendations.

- **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**
- **Expand community outreach and education**
- **Continue improving Laboratory engineering services, administration, and infrastructure**



This orthogonal transfer array, an architecture of orthogonal transfer charge-coupled devices developed at Lincoln Laboratory, is one of 60 installed in the large digital camera used in the prototype telescope (right) of Pan-STARRS (Panoramic Survey Telescope and Rapid Response System), a wide-field imaging facility being built at the University of Hawaii's Institute for Astronomy for use in sky surveys. This background image of the M51 galaxy was captured by the prototype telescope during its commissioning and debugging in early 2008.

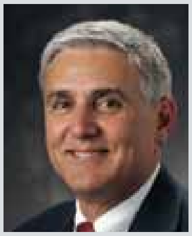
NEW LEADERSHIP



Marc D. Bernstein
Associate Director

Associate Director

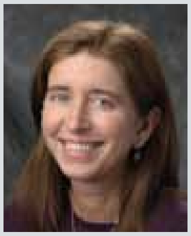
Dr. Marc Bernstein became Associate Director on 1 July 2009. He will focus on execution of large prototyping programs and pursue broad tactical and strategic initiatives.



Steven R. Bussolari
Director's Office Staff for Strategic Initiatives

Director's Office Staff, Strategic Initiatives

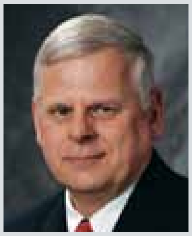
Dr. Steven Bussolari joined the Director's Office, with responsibility for strategic initiatives, on 1 August 2009. He will lead the ongoing evolution of the Laboratory's Five-Year Mission Plan and assist in the Laboratory's interactions with senior leaders in government and industry.



Bernadette Johnson
Chief Technology Officer

Chief Technology Officer

Dr. Bernadette Johnson joined the Director's Office Staff as the Chief Technology Officer on 1 July 2009. She will be responsible for developing the Laboratory's long-term technology strategy and for promoting collaborative research with MIT campus.



John E. Kuconis
Executive Officer
Director's Office

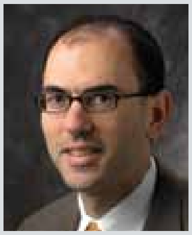
Director's Office Staff, Executive Officer

John E. Kuconis joined the Director's Office Staff as Executive Officer in April 2009. He is responsible for executing tactical Director's Office initiatives, coordinating technical interactions for senior-level Laboratory visits, overseeing the Lincoln Laboratory Community Outreach (LLCO), and serving as Executive Secretary of the Laboratory Steering Committee.

Hsiao-hua K. Burke
Division Head,
Air and Missile Defense Technology Division

Division Head, Air and Missile Defense Technology

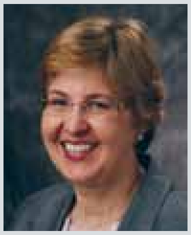
Dr. Hsiao-hua K. Burke was appointed Head of the Air and Missile Defense Technology Division on 1 July 2009. She will have oversight of the Laboratory's air and ballistic missile defense programs.



Eliahu H. Niewood
Division Head,
Engineering Division

Division Head, Engineering

Dr. Eliahu H. Niewood was appointed Head of the Engineering Division in July, 2009. He will provide leadership for the division's engineering programs and develop its future strategic direction.



Cheryl L. Overs
Department Head,
Financial Services Department

Department Head, Financial Services Department

Cheryl L. Overs joined Lincoln Laboratory in 2009 to lead the Financial Services Department. She is responsible for centralizing the financial services function and managing the financial operations for the Laboratory, which include accounting services, financial planning and reporting, property management, and travel services. Ms. Overs will focus on improving management reporting and streamlining financial processes to enable the Laboratory's research missions.

TECHNOLOGY DEVELOPMENTS

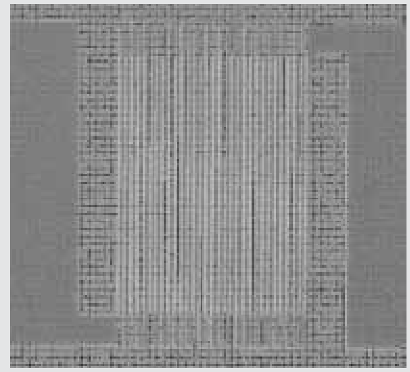
The MIT Lincoln Laboratory Chief Technology Office (CTO) is responsible for developing a long-term technology strategy for the Laboratory and for establishing and growing strategic technical relationships with the Defense Advanced Research Projects Agency, Office of Naval Research, Army Research Office, Air Force Research Laboratory, and other Service program offices. The CTO promotes collaborative research with MIT and other academic research institutions. In 2009, collaborations with MIT research groups continued in the areas of autonomous sensing and robotics, social network analysis, and decision support.

This past year, the CTO extended the Laboratory's technology position in advanced electronics; biological-chemical sensing; photonics and single-photon communications; intelligence, surveillance, and reconnaissance sensing; and decision support.

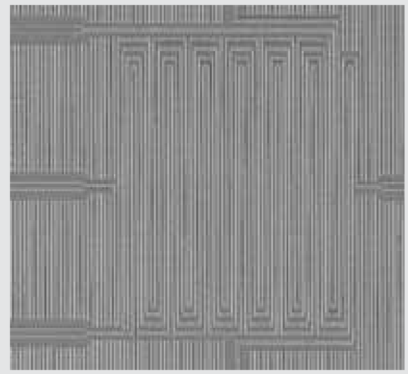
Notable achievements this past year included the following:

- The Laboratory developed a novel infrared digital focal plane that brings a new level of image uniformity and noise reduction to both midwave and longwave infrared systems. A large camera field of view with a high frame rate was demonstrated in both wavebands.
- Two years ago, a new concept for treating mammalian cells infected with double-stranded RNA viruses was tested in vitro against a number of viruses infecting human lung tissue. Last year, in vivo testing in mice infected with influenza began. This project has transitioned to government sponsorship.
- MIT campus and Lincoln Laboratory jointly developed superconducting, niobium nitride (NbN) photon-counting detector arrays for extremely sensitive laser communications systems. World-record speed and detection efficiency were achieved for photon-counting detectors in free-space optical communications systems. This technology is supporting a NASA program to demonstrate an ultrasensitive wideband optical communication link to an orbiting lunar satellite.

The Laboratory's technology investments have also enabled new mission concept demonstrations in the homeland protection, net-centric operations, and counterterrorism/counterinsurgency areas. These projects integrate and validate advanced technology concepts through field tests and end-to-end demonstrations.

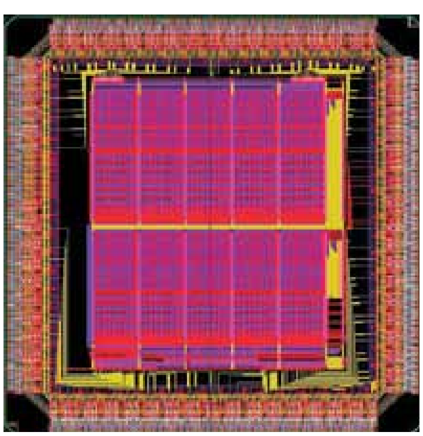


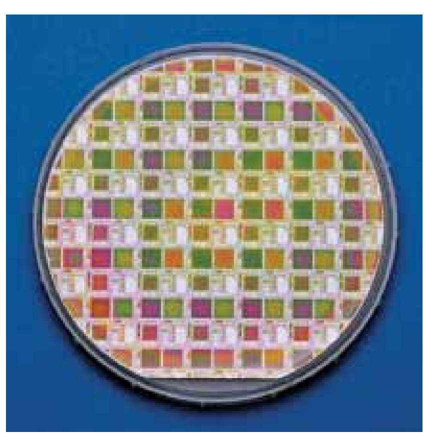
(a)

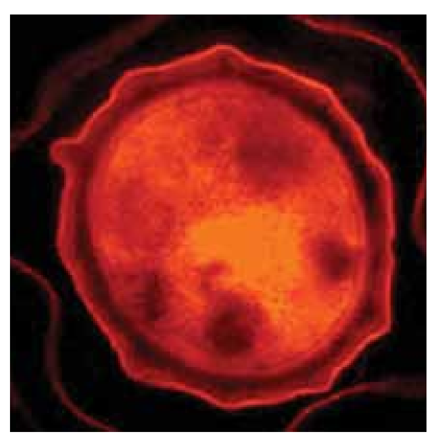


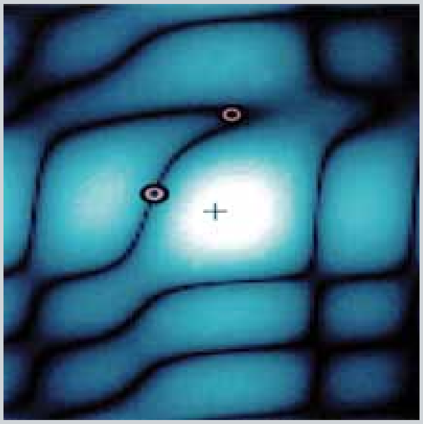
(b)

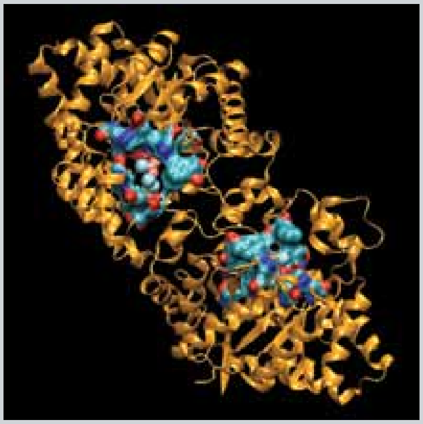
In the early 2000s, single-photon-counting niobium nitride (NbN) detectors were very fast but were limited to a detection efficiency of ~3% at laser communication wavelengths. A joint collaboration among MIT Lincoln Laboratory, the MIT Research Laboratory for Electronics (RLE), the University of Rochester, and Moscow State University fostered the development of these photon-counting detectors for highly efficient, ultrasensitive laser communications receivers. Further development at RLE and the Laboratory led to improved lithographic fabrication techniques, and the first MIT-fabricated detectors were tested in February 2005 (Figure a). By September 2005, the NbN detectors reached a world-record 781 Mbit/sec at a ~0.5 detected photon/bit. The addition of an optical cavity to the detector and improved fabrication technology resulted in unrivaled detection efficiencies of 57% in 2006. Ultimately, understanding the physical limitations on individual detector speed led to the use of detector arrays, such as the interleaved, four-element detector illustrated in Figure b, to further increase high-speed performance. In the future, photon-counting high-speed detectors will be the technology of choice in building a deep-space laser communications network servicing all NASA planetary exploration missions.











MIT LINCOLN LABORATORY

MISSION AREAS

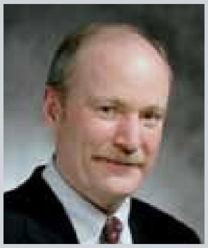
- Space Control
- Air and Missile Defense Technology
- Communications and Information Technology
- Intelligence, Surveillance, and Reconnaissance Systems and Technology
- Advanced Electronics Technology
- Tactical Systems
- Homeland Protection
- Air Traffic Control

TECHNOLOGY IN SUPPORT OF NATIONAL SECURITY

SPACE CONTROL

The Space Control mission develops technology that enables the nation's space surveillance system to meet the challenges of space situational awareness. Lincoln 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.

Leadership

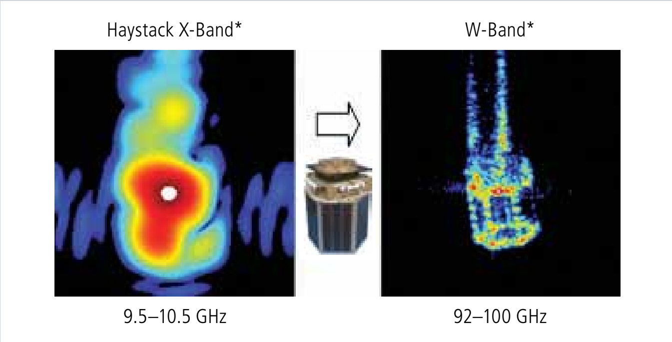

Dr. Grant H. Stokes

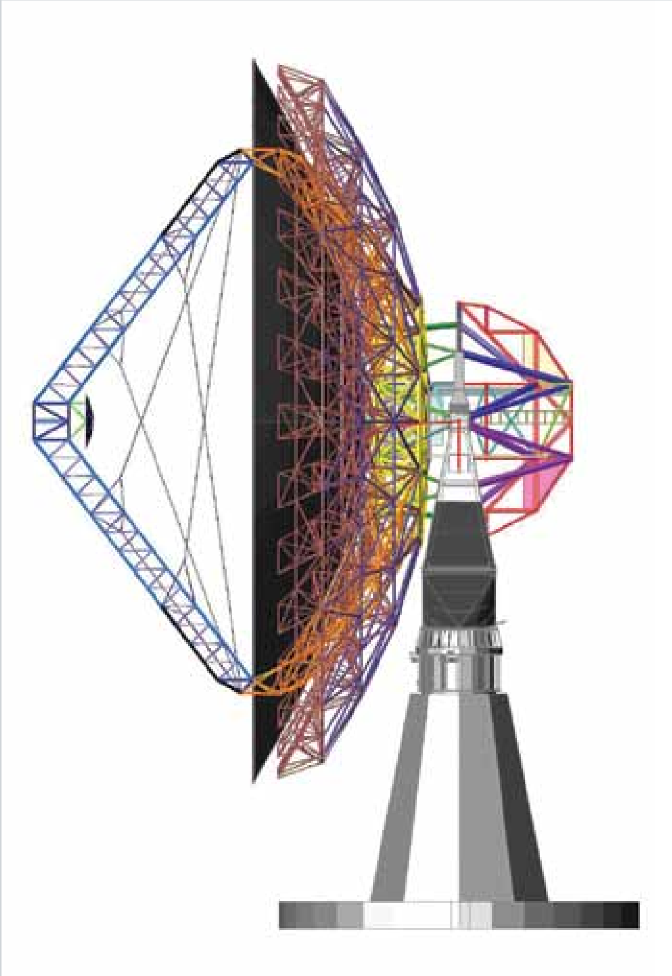

Mr. Lawrence M. Candell


Mr. Craig E. Perini

Haystack Ultrawideband Satellite Imaging Radar (HUSIR)


The antenna detailed design and risk-reduction phases were completed this year.





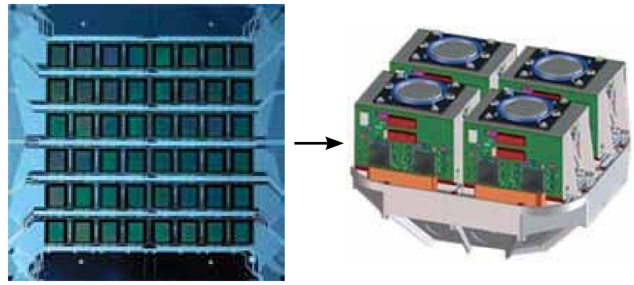
Haystack upgrade to W-band (92–100 GHz) will enable inverse synthetic aperture radar (ISAR) imaging of satellites in low Earth orbits with much higher resolution than possible with the current X-band radar.

* ISAR images of a satellite model using compact range data

Principal 2009 Accomplishments

- Under DARPA/TTO sponsorship, Lincoln Laboratory is completing the development of the Space Surveillance Telescope (SST). The system is being installed at the Atom Site on the White Sands Missile Range in New Mexico. Over the next year, before transitioning the system to the Air Force as part of its expanded Space Surveillance Network, the Laboratory and Air Force Space Command will be evaluating the system and its mission utility for detecting and tracking microsatellites.
- The Optical Processing Architecture at Lincoln has reached significant maturity in its development. Successfully tested deliveries have been made to support several operational systems planned to come online in FY10, including the SST in New Mexico, the ground station for the Air Force's Space-Based Space Surveillance (SBSS) satellite, and the Experimental Sensor Integration Prototype.
- The future Air Force Space Fence system will require new capability for dedicated, timely, uncued detection and tracking of small objects in low (primary) and medium (secondary) Earth orbits. The Laboratory is defining system requirements and developing a performance evaluation system.
- The Space Red Team continues to expand its investigations into risks to the U.S. space infrastructure and into means to mitigate them. Results of a national-level study on both these risks and the means to assure continuation of critical services provided by space systems have been briefed broadly across the space community.
- Lincoln Laboratory is providing critical technical support to the development of the National Oceanic and Atmospheric Administration's future Geostationary Orbiting Environmental Satellite (GOES). Focus is on improving the design of new flight instruments, including the Advanced Baseline Imager, Solar Ultraviolet (UV) Imager, Lightning Mapper, and Extreme UV and X-ray Irradiance Sensors.
- To enable wide-area infrared persistent surveillance, the Laboratory has developed a novel infrared sensor incorporating a digital focal plane array. The sensor's unique features include high-speed digital outputs that accommodate high-speed scanning data rates and up to 256 time-delay-and-integrate gain stages to maintain signal-to-noise ratio during high-speed scanning.
- The Extended Space Sensors Architecture (ESSA), an Advanced Concept Technology Demonstration and the test bed and development vehicle for bringing space situational awareness (SSA) into the net-centric realm, has had several deliveries and demonstrations with the Joint Space Operations Center. Under ESSA, additional specific space surveillance sensors have been made net-centric (i.e., their data is registered and discoverable), and the information exploitation engines will be developed to feed off the databases and sensors.

Lincoln Laboratory has a long history of contributing to the National Polar Operational Environmental Satellite System (NPOESS) Cross-track Interferometer Sounder (above). The Laboratory's work has extended from breadboard instrument development to ongoing test, evaluation, and pre-flight calibration.



MASIVS Focal Plane   Four Camera Modules

The Multi-Aperture Sparse Imager Video System (MASIVS) is a novel electro-optical sensor with key features including an 880-megapixel color imaging capability and a two-frame/second readout. This system will provide an order of magnitude increase in pixel count over existing systems.

Future Outlook

- Space Control activity will move from large-scale sensor development toward information extraction, integration, and decision support. The challenges will be to incorporate the widest possible set of data and to automate the process of generating customized actionable products for a wide range of users. Operator and developer acceptance of ESSA is critical to evolving to a machine-to-machine driven SSA capability that can respond on the 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.
- The sensor systems currently under development will bring new capability to the Space Control mission area. It will take considerable time and effort to fully assess the information content available from the new sensors and make it most useful to operators.
- Lincoln Laboratory is currently pursuing several initiatives in the Space Control area. These include development of the next generation of sensor systems as well as the downstream processing/information extraction systems. Projects may include the following:
  - A small-aperture space-based space surveillance system to provide wide-area search of the geosynchronous belt every 90 minutes, with sensitivity equivalent to SBSS Block 10
  - Bistatic and multistatic radar technology and techniques for fusing radar and optical imagery for space-object identification
  - Climate-change monitoring that will be conducted by assessing the utility of using very-long-wave infrared radiation for space-based sensing and by exploiting a historical 30-year database of satellite sounding data to evaluate climate trends

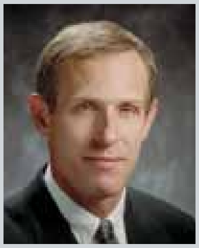
The observatory enclosure for the Space Surveillance Telescope was in its final stages of construction in July 2009. The system is being installed at the Atom Site on the White Sands Missile Range in New Mexico.

AIR AND MISSILE DEFENSE TECHNOLOGY

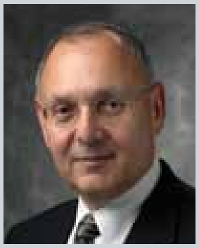
In the Air and Missile Defense Technology mission, Lincoln Laboratory works with government, industry, and other laboratories to develop integrated systems for defense against ballistic missiles, cruise missiles, and air vehicles in tactical, strategic, and homeland defense applications. Activities include 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. The program includes a focused evaluation of the survivability of U.S. air vehicles against air defense systems. A strong emphasis is placed on the rapid prototyping of sensor and system concepts and algorithms, and the transfer of the resulting technologies to government contractors responsible for the development of operational systems.

Leadership

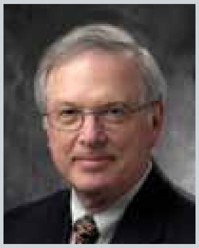
Dr. Hsiao-hua K. Burke



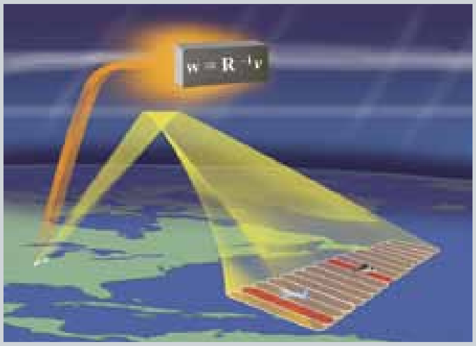
Dr. Andrew D. Gerber



Mr. Gerald C. Augeri



Mr. Dennis J. Keane



In collaboration with the Australian Defence Science and Technology Organisation and using the Jindalee Operational Radar Network in Australia, Lincoln Laboratory completed two demonstrations of critical components for a next-generation over-the-horizon (OTH) surveillance radar. New waveforms and adaptive processing techniques significantly reduced the effects of multiple propagation paths on target detection.

Principal 2009 Accomplishments

- On 20 February 2008, the United States successfully intercepted a disabled U.S. satellite over the Pacific Ocean by using an SM-3 Standard Missile. The satellite's reentry into the Earth's atmosphere posed a threat to population centers because of the toxic hydrazine fuel on board. Lincoln Laboratory was a key contributor to the mission planning, execution, and post-intercept assessment.
- A combined ballistic missile defense (BMD) and space situational awareness concept demonstration was carried out at the Reagan Test Site and the Lexington Space Situational Awareness Center. The demonstration showed how net-centric services can perform real-time brokering and control of sensors between the BMD and Space missions, and highlighted key net-centric technologies, including sidecars, services, data exposure, and machine-to-machine tasking. Future demonstrations will extend into the intelligence, surveillance, and reconnaissance domain.
- The Reagan Test Site (RTS) successfully used the newly deployed command-and-control capability known as the RTS Distributed Operations as the operational mission control center for an Air Force intercontinental ballistic missile test. This capability will transition to the operational baseline in 2009.
- An initial next-generation radar open systems architecture (ROSA II) was completed and integrated into several operational sidecars for ballistic missile test and intelligence data collections. The software utilizes a network-centric middleware layer to allow rapid integration of new technologies and remote sensor control and monitoring. The software architecture is being further developed as a data and signal processing system for network-centric phased-array radars.
- The Laboratory worked with the Missile Defense Agency and the Office of the Secretary of Defense to define technical architectures for an integrated air and missile defense of the U.S. homeland. The Laboratory conducted risk reduction for an initial prototype of this architecture, which could augment the Integrated Air Defense System currently in place in the National Capital Region. This prototype architecture provides a defense against low-flying aircraft, cruise missiles, and short-range ballistic missiles launched from a ship off the U.S. coastline.

The X-band Transportable Radar (XTR-1) was integrated at the Lincoln Space Surveillance Complex in Westford, Massachusetts. The radar utilizes the Laboratory's Radar Open Systems Architecture (ROSA).

To provide capability against future advanced missile threats to Navy platforms, Lincoln Laboratory is developing an enhanced electronic attack prototype for use on surface platforms.

Future Outlook

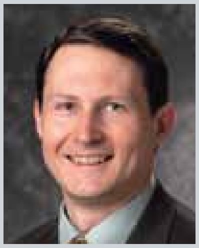
- Air Defense has been a key mission area for Lincoln Laboratory since its origin in 1951, when the Laboratory was established to develop the first air defense system for the U.S. homeland. The Laboratory is in the process of strengthening its Air Defense mission area, with focus on Service and homeland air defense needs. Current major growth areas include new electronic warfare and radar capabilities for the Navy, and prototype architectures and technologies for homeland air defense.
- Lincoln Laboratory continues to have a significant role in characterizing the capabilities and limitations of deployed ballistic missile defense components and in helping to develop, refine, and verify tactics, techniques, and procedures to optimize performance. The Laboratory is also actively engaged in the analysis, development, testing, and implementation of new capabilities. Areas of particular focus are system-wide tracking and discrimination, system-level testing, and advanced counter-countermeasures techniques.

The Laboratory is upgrading the optical sensors at the Reagan Test Site to an all-digital system.

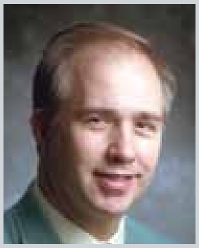
COMMUNICATIONS AND INFORMATION TECHNOLOGY

In the Communications and Information Technology mission, the Laboratory works to enhance the capabilities of current and future U.S. global defense communications networks (space, air, land, and sea) in the transport and knowledge domains. Emphasis is placed on developing architectures; identifying, prototyping, and demonstrating components, subsystems, and systems; and then transferring this technology to industry for use in operational systems. Current efforts span all network layers (from physical to application), with primary focuses on satellite communications, aircraft and vehicle radios and antennas, tactical networking, language processing, net-centric operations, and cyber operations.

Leadership

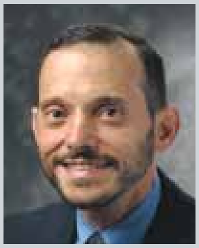


Dr. J. Scott Stadler

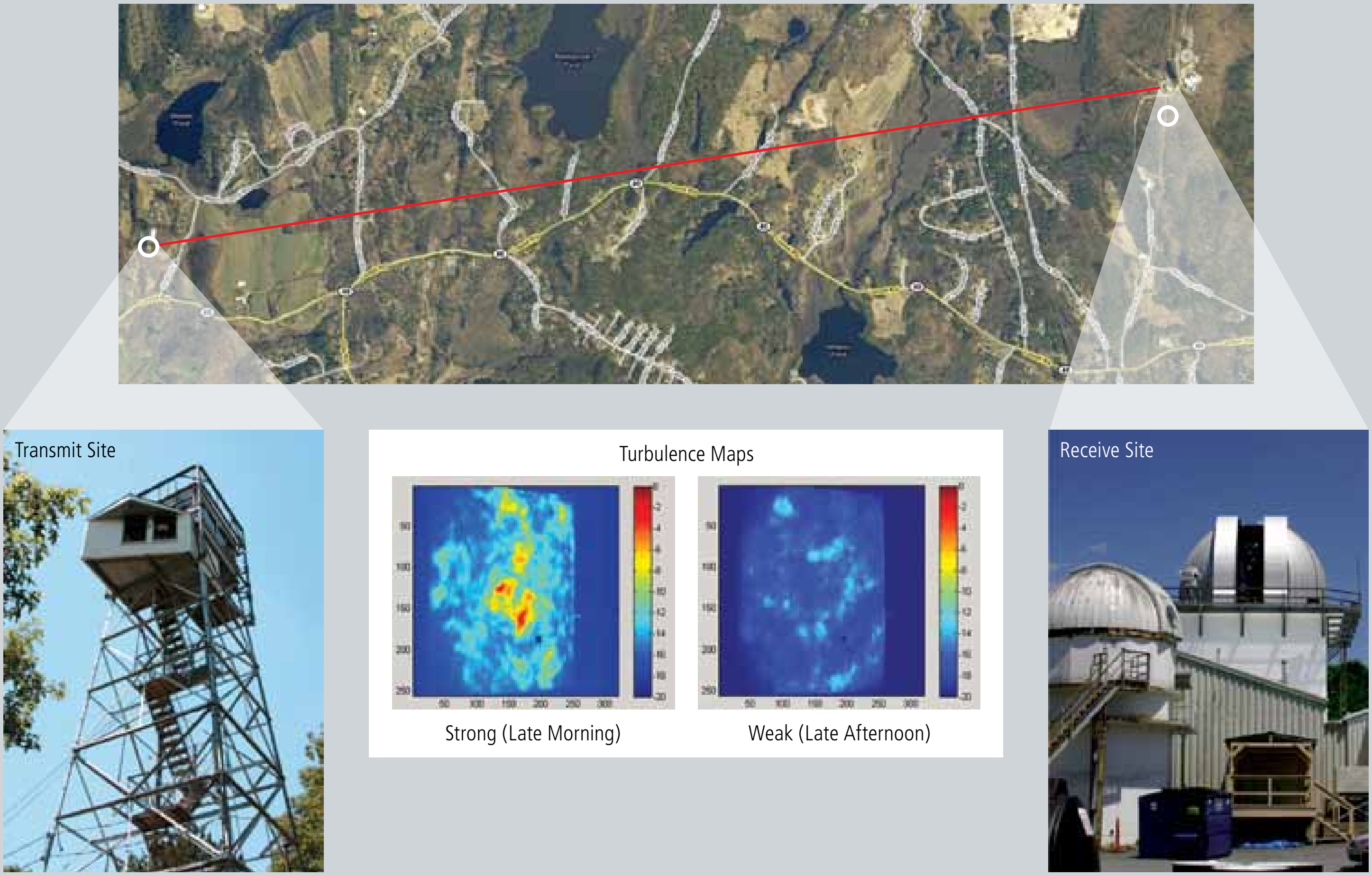


Dr. Roy S. Bondurant

Mr. Stephan B. Rejto



Dr. Marc A. Zissman



This 2.7 Gbps lasercom system combined low-power operation and small apertures with spatial and temporal diversity techniques to enable high-reliability operation on a 5.4 km terrestrial link under stressing atmospheric conditions representative of a 20 km aircraft-to-ground link. The terminals included robust pointing, acquisition, and tracking systems suitable for use on maneuvering aircraft and will be flight tested this year.

Principal 2009 Accomplishments

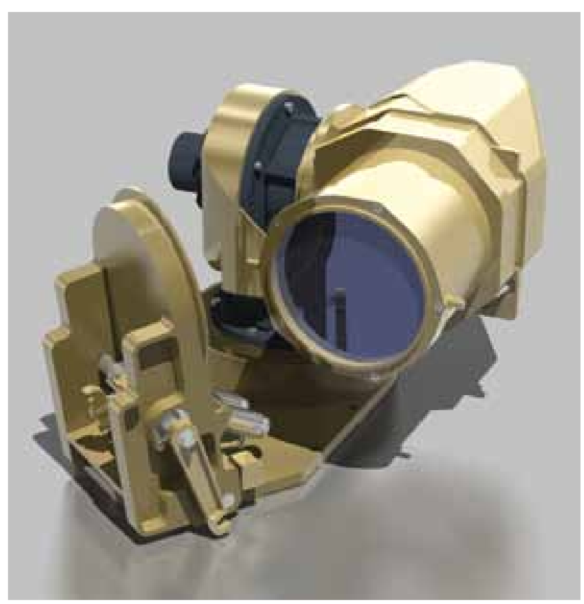
- Lincoln Laboratory led a multi-Service effort to develop a reference architecture for advanced satellite communications terminals. An early prototype of a communications-on-the-move vehicle was completed and demonstrated with a Milstar satellite.
- Key communication waveform development activities were initiated for protected unmanned aerial vehicle (UAV)–based range extension and future airborne networking platforms.
- The Laboratory built a high-data-rate waveform for airborne intelligence, surveillance, and reconnaissance (ISR) readout over the Wideband Global SATCOM (WGS) system, performed over-the-air testing, and transferred the design to industry.
- A high-speed forward error correction and interleaving system that was successfully demonstrated will enable reliable high-data-rate laser communications in fading environments.
- The Laboratory created, hosted, and maintained a DoD-wide repository of data and models needed to conduct wireless networking research. These data and models included traffic, mobility, and channel characteristics.
- Speech systems for forensic speech processing were extended to include state-of-the-art noise suppression, speech enhancement, and speaker comparison tools.
- The Laboratory developed and tested algorithms for Social Network Analysis and Intent Recognition, using a new Terror Attack Description Language that models potential attack scenarios for automated detection.
- Lincoln Laboratory extended the capabilities of the Lincoln Adaptable Real-time Information Assurance Testbed (LARIAT) cyber test and evaluation environment, increasing the scope and fidelity of large-scale environment emulation and further automating range operations. LARIAT was deployed on national ranges in support of exercises and evaluations.
- A Laboratory terminal and the Family of Beyond-line-of-sight Terminals (FAB-T) Milstar terminal were flight tested on board the Paul Revere aircraft.
- The Laboratory performed flight testing of a 20 GHz variable inclination continuous transverse stub array antenna that was built in collaboration with industry.
- High-data-rate laser communications were demonstrated by using a high-efficiency superconducting photon-counting detector-based receiver over a 1.7 km free-space link.
- The Laboratory designed a terminal that will be flown on a lunar orbiter to demonstrate laser communications and ranging.

A combined ballistic missile defense/space situational awareness mission concept demonstration employed the Net-Centric Toolkit to enable sensors from different domains to be used collaboratively for mission-critical applications.

Advanced extremely high-frequency (AEHF) interim command-and-control terminals completed acceptance testing and were deployed to Schriever and Vandenberg Air Force bases to support AEHF operations.

Future Outlook

- Lincoln Laboratory will use the interim payload command-and-control capability to support initial operation of the advanced extremely high-frequency (AEHF) satellite.
- The Laboratory will enhance the Net-Centric Toolkit, a collection of Net-Centric Enterprise Service (NCES)–compatible services that focus on enabling cross-mission interoperability of advanced sensor and command-and-control systems.
- Lasercom technology development efforts will continue to enable increased data rates and improved sensitivities in high-performance systems.
- The development, deployment, and evaluation of advanced cyber tools will continue. These efforts will help to evaluate and improve the robustness of future DoD systems.
- The Laboratory will further develop Social Network Analysis and Intent Recognition algorithms and transfer the technology to operational environments.

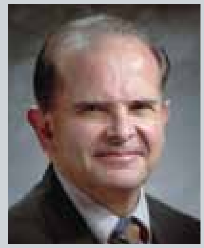


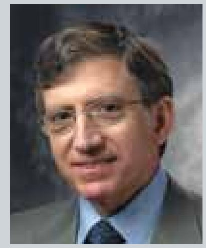
This is a rendition of the laser communication terminal that will be flown to the moon in 2012.

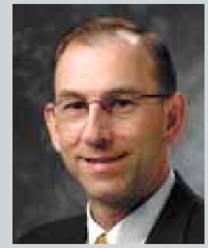
INTELLIGENCE, SURVEILLANCE, & RECONNAISSANCE SYSTEMS AND TECHNOLOGY

The Intelligence, Surveillance, and Reconnaissance (ISR) Systems and Technology mission conducts research and development into advanced sensing concepts, signal and image processing, high performance computing, networked sensor architectures, and decision sciences. This work is focused on providing improved surface and undersea surveillance capabilities for problems of national interest. The Laboratory's ISR program encompasses airborne imaging and moving target detection radar, RF geolocation systems, electro-optic imaging, and laser radar. For such systems, the Laboratory typically performs phenomenology analysis, system design, component technology development, and significant experimentation. Successful concepts often develop into experimental prototype ISR systems, sometimes on surrogate platforms, that demonstrate new capability in operationally relevant environments.

Leadership


Mr. David R. Martinez


Dr. Curtis W. Davis III

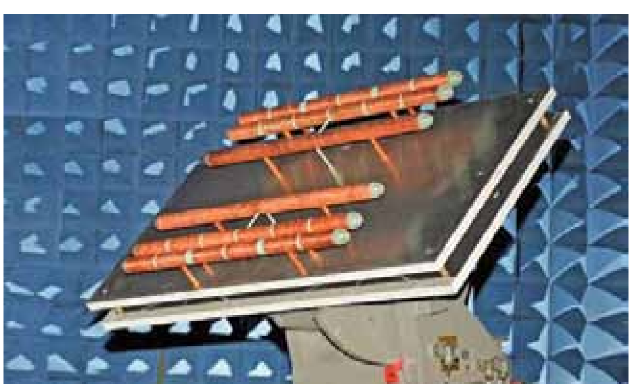

Dr. James Ward


USCG HH60

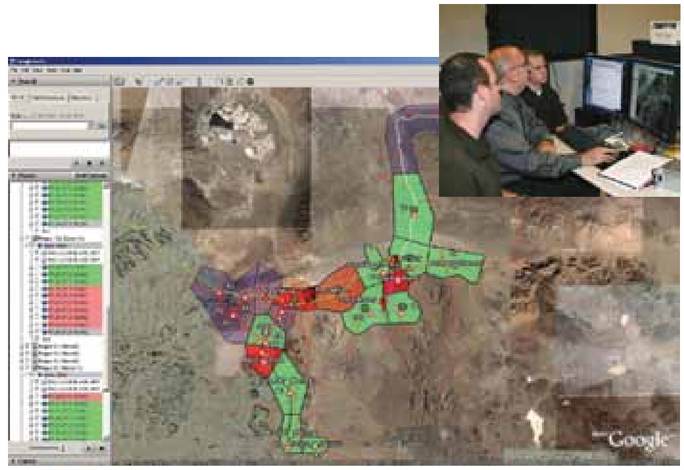
An ISR demonstration conducted with Laboratory airborne sensors and U.S. Coast Guard participation in Boston Harbor emulated a homeland defense scenario.

Principal 2009 Accomplishments

- A new middleware library, the Parallel Vector Tile-Optimized Library (PVTOL), provides a scalable, portable, and highly productive parallel programming infrastructure targeted for multicore processor chips such as the IBM Cell BE processor. The PVTOL library components were used in a Cell-based real-time processor for a next-generation wide-area persistent video surveillance sensor.
- The Lincoln Laboratory Grid (LLGrid)—a large-scale, interactive computing capability that supports algorithm development and simulation—achieved several milestones. The user base for the LLGrid expanded to more than 300 users. The LLGrid executed a terabyte-scale problem that is the largest, in data size, computing problem ever run on a grid computing system.
- The Laboratory developed radar modes and associated signal processing for enhanced ground moving target detection. An initial discrimination architecture to distinguish between different target types was shown to be effective with recorded experimental data. This technology is being integrated into a real-time processor for a new unmanned aircraft radar.
- Two prototype sensors for future surveillance and reconnaissance aircraft were built to detect a broad set of target signatures. These systems consist of broadband antenna arrays, high-performance signal processors, and specialized signal processing algorithms. Prototype sensors were demonstrated on a Twin Otter airplane, and the system is being operationalized on a government-furnished aircraft.
- In a major step toward establishing a service-oriented net-centric ISR test bed at the Laboratory, a demonstration of sensor and command-and-control integration was conducted and involved representative components of homeland air defense, air traffic control, and maritime ISR. A real-time service infrastructure was demonstrated in the maritime threat scenario shown at left.
- Lincoln Laboratory developed passive sonar adaptive beamforming algorithms for submarine bow sphere arrays. This work demonstrated significant detection improvements in cluttered environments, and the signal processing is transitioning into the U.S. Navy submarine fleet.
- Concepts for using terahertz (THz) radiation to detect trace explosives on a person's hair were investigated. An ultrasensitive THz receiver leverages mature technology at the near-infrared wavelengths to nonlinearly up-convert the THz signal to an optical signal, which is then detected using Geiger-mode avalanche photodiode detector arrays.
- A very-high-data-rate, non-line-of-sight data link employing new wideband waveform designs, multiple-antenna systems, and space-time coding demonstrated a data rate of 1 Gbps over 145 m in heavy multipath and error-free performance with total power less than 200 mW.



New RF sensing capabilities, such as this wideband planar antenna, were prototyped on a Twin Otter plane shown on the opposite page.

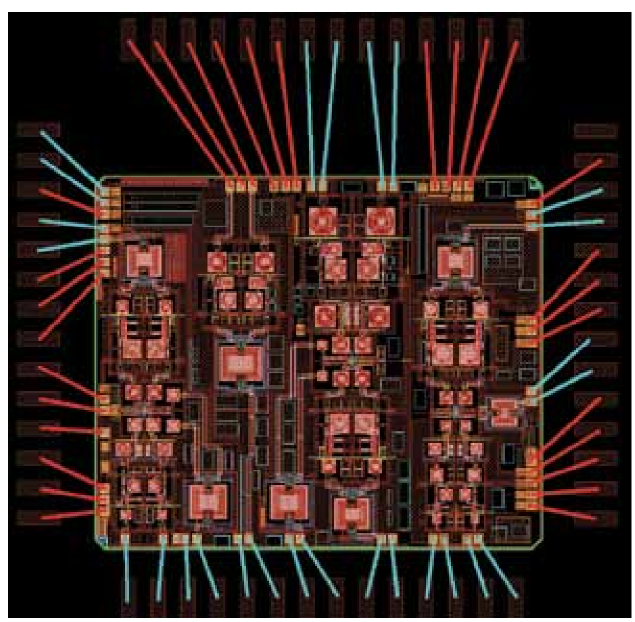


The Fusion Exploitation Tool provides automated indications and warning within the Google Earth geospatial visualization framework. Red areas indicate regions of anomalous activity.

Future Outlook

The ISR mission expects an increasing national investment in developing and fielding improved capabilities for irregular and conventional warfare; efforts will provide much better integration of ISR capabilities between the armed services and intelligence agencies. Future Lincoln Laboratory ISR research will likely include the following activities:

- Developing imager, processing algorithm, and processor technologies to improve the capabilities of persistent electro-optical systems
- Miniaturizing receiver and processor payloads to enable improved radar and geolocation systems for unmanned vehicles
- Developing a net-centric ISR architecture test bed that will include space and airborne ISR assets, sensor exploitation, and decision support as part of a multi-intelligence demonstration and technology development capability
- Implementing graph-based exploitation algorithms on high performance computing architectures, including large-scale "clouds" of commodity processors, and developing new computing architectures to enable the processing for these algorithms to run on small form factors

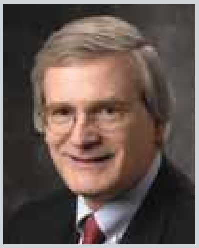


This RF receiver-on-a-chip is being developed to provide high performance and very low size, weight, and power.

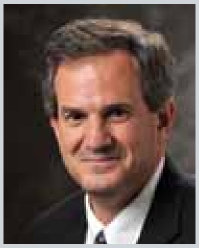
ADVANCED ELECTRONICS TECHNOLOGY

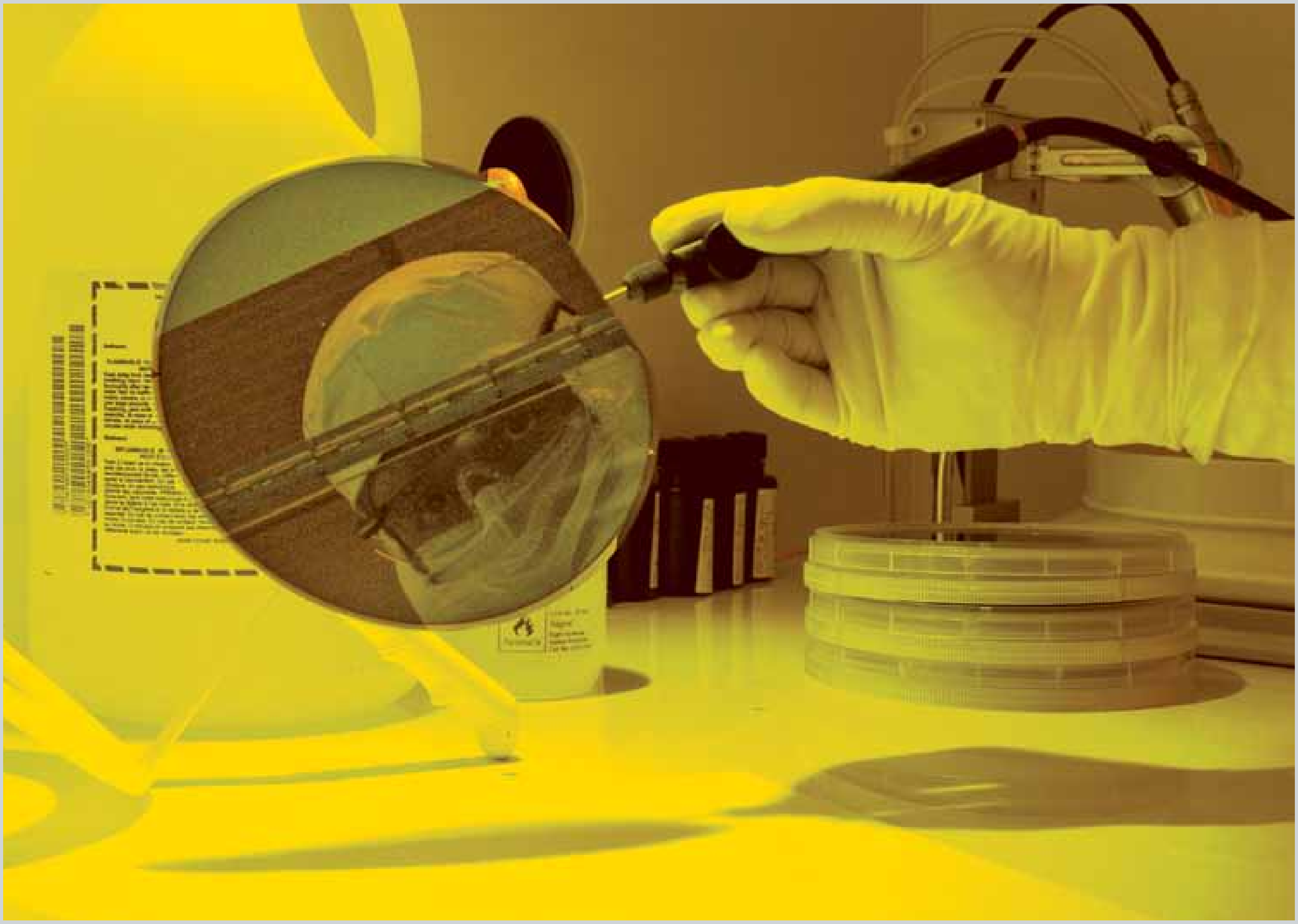
Research and development in Advanced Electronics Technology (AET) focus on the invention of new devices, the practical realization of those devices, and their integration into subsystems. Although many of these devices continue to be based on solid-state electronic or electro-optical technologies, recent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

Leadership


Dr. David C. Shaver

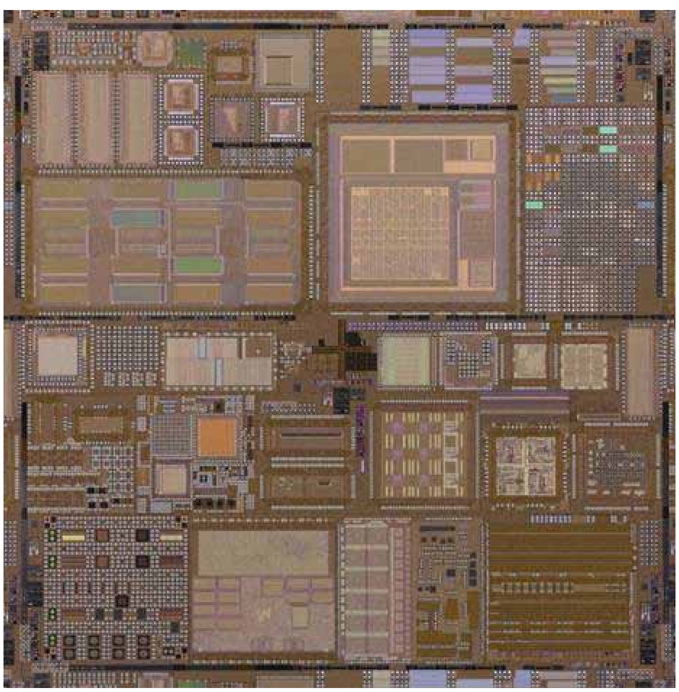

Dr. Charles A. Primmerman


Dr. Craig L. Keast

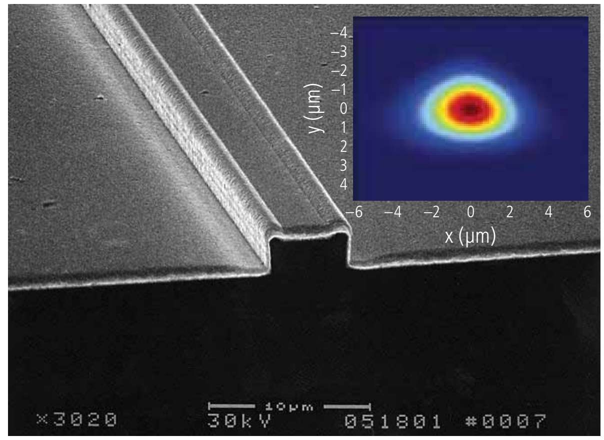

An indium-phosphide wafer is bonded atop a silicon wafer as a development step in fabricating 3-D stacked structures for infrared detector arrays. The top wafer will hold the photodiode pixels, and the bottom wafer will contain transistor circuits for reading out each pixel. This approach combines sophisticated electronics with high-efficiency photodetection of infrared radiation.

Principal 2009 Accomplishments

- Significant improvements in cryogenic Yb:YAG lasers have been achieved, including higher CW power, demonstrations of ultra-short-pulse operation, and lasers with the needed form-factor and reliability to be useable in DoD applications.
- A diagnostic system for the Joint High Power Solid State Laser (JHPSSL) was completed, and the system was taken to the first of the JHPSSL contractor sites to begin characterization of the laser.
- In the development of photon-counting detectors, the Laboratory has made advances in extending photon-counting avalanche photodiodes to shortwave and midwave infrared wavelengths; in improving reliability; and in increasing array size, detection efficiency, and other critical performance parameters.
- High performance superwideband compressive receivers have been used in increasingly sophisticated airborne demonstrations, and substantial improvements have been made in performance and in reducing size, weight, and power.
- Through the initiation of a new multiproject run, the Laboratory is investigating the application of its unique 3-D integrated circuit technology to a broader range of advanced digital and mixed-signal circuits.
- Following up on a successful FY08 feasibility demonstration of standoff detection of trace chemical explosives via ultraviolet (UV) fluorescence, the Laboratory has made progress in understanding the impact of clutter sources on the UV fluorescence technique. More detailed spectroscopic analysis will provide critical data to assess the feasibility of potential clutter-mitigation approaches.



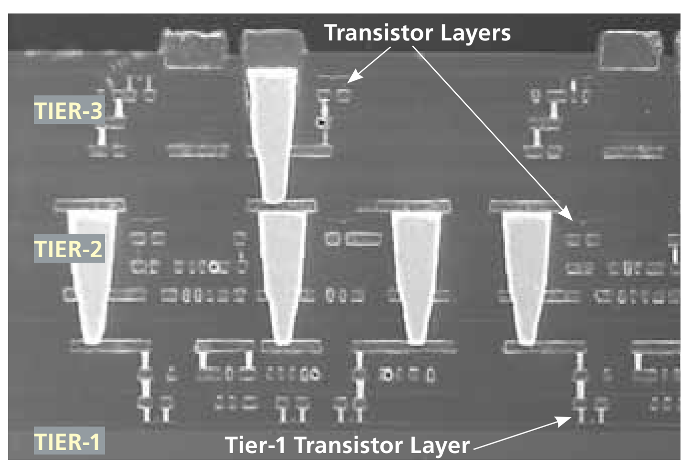
This photo depicts many experimental circuits fabricated in the 3-D multiproject wafer run. The Laboratory is investigating applications of its unique integrated circuit technology to advanced digital and mixed-signal circuits.



The larger image is a micrograph of the ridge waveguide in a slab-coupled optical waveguide laser, and the inset shows the near-field single-mode pattern of the infrared output beam.

Future Outlook

- The scope of applications that could use Geiger-mode (GM) single-photon detection technology continues to expand, ranging from laser radar to communications to passive low-light-level imaging. These applications require not only improved avalanche photodiode (APD) arrays at a variety of wavelengths but also increasingly complex per-pixel readout electronics. Significant development work is needed to better understand GMAPDs, to improve their reliability, and to characterize their performance in demanding environments.
- The need for high-energy laser (HEL) systems persists. Supporting technologies for beam control and target acquisition for HEL systems are current research interests. In support of the long-term vision of efficient, scalable, modular all-electric lasers, both spectral and coherent beam-combining techniques are being developed for application to diode pumps, fiber lasers, and direct diode-laser systems.
- The use of the slab-coupled optical waveguide (SCOW) structure continues to provide significant performance improvements in a variety of device structures optimized at different wavelengths and for different applications, such as coherent combining of laser arrays and amplifiers for low-noise oscillators.
- The exploitation of advanced RF structures, such as micro-electromechanical (MEM) capacitive switches and compressive filters, in combination with digital processors, will push innovation into broadband receivers for important new applications. The transition to foundry production of the recently demonstrated low-loss, long-life, fully packaged MEM switch will accelerate the deployment of compact, reconfigurable RF systems.



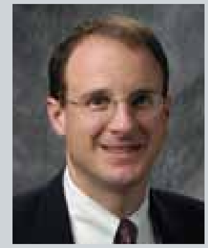
This cross-sectional electron micrograph shows three tiers of the 3-D circuit process.

TACTICAL SYSTEMS

Leadership

Dr. Robert T-I. Shin

Dr. Robert G. Atkins



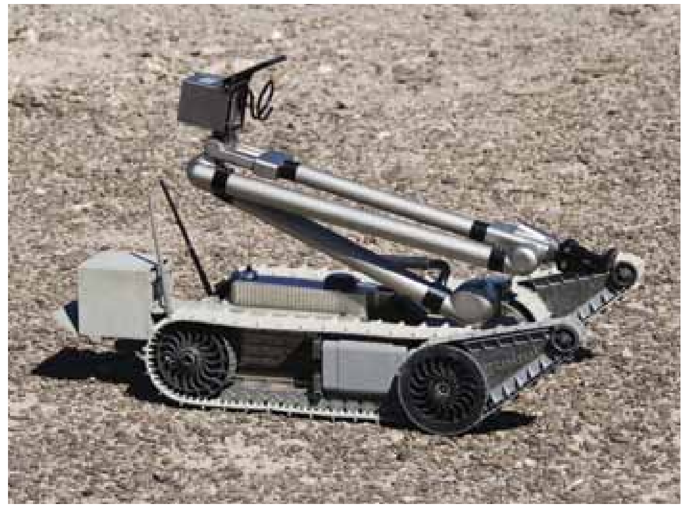
Dr. Kevin P. Cohen

In the Tactical Systems mission, Lincoln Laboratory focuses on assisting the Department of Defense to improve the acquisition and employment of various tactical air and counterterrorist systems. The Laboratory does this 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. The Tactical Systems area is characterized by a very tight coupling between the Laboratory's efforts and the DoD sponsors and warfighters involved in these efforts. This tight coupling ensures that the analysis that is done and the systems that are developed are relevant and beneficial to the warfighter.

The Laboratory operates a Twin Otter aircraft-based Airborne Counterterrorism Testbed, which allows rapid innovation and testing of new counterterrorism-related capabilities. The novel synthetic aperture radar capability pictured above is one of the systems for which the test bed was used.

Principal 2009 Accomplishments

- The Laboratory's comprehensive assessment of options for U.S. Air Force airborne electronic attack against foreign surveillance radars involved systems analysis of proposed options, development of detailed models of threat surveillance radars and their electronic protection systems, and testing of electronic attack systems and surveillance radars. A major focus has been the development of a test infrastructure, including a new Airborne Countermeasures Test System (ACTS II) and a new sidecar system for implementing advanced electronic protection on an older surveillance radar.
- The impact of digital RF memory–based electronic attack on air-to-air weapon system performance was assessed through systems analysis and hardware-in-the-loop testing.
- For an evaluation of the capabilities and limitations of infrared sensors and seekers to support beyond-visual-range passive air-to-air engagements, the Laboratory is performing systems analysis, developing detailed models of infrared search-and-track systems and imaging infrared missile seekers, and conducting both laboratory and captive-carry testing of various surrogate systems.
- A number of studies examined the results of exporting advanced military systems. One of the exports considered was the Large Aircraft InfraRed CounterMeasure (LAIRCM) system. The Laboratory evaluated the impact on the susceptibility of U.S. aircraft if LAIRCM were exported and identified ways to minimize that impact.
- An advanced airborne signals intelligence (SIGINT) capability was demonstrated both in local test flights and in a continental U.S. (CONUS) operational exercise. This capability leverages receiver hardware, antennas, and detection algorithms developed by the Laboratory over the past several years. Ground-vehicle integrated and man-portable versions of the system were also rapidly developed at warfighter request and are now being transitioned to operational use.
- A prototype robot-mounted sensor for use by explosive ordnance disposal teams was successfully proven in CONUS demonstrations and in Army capabilities and limitations testing. The prototype has been transitioned to warfighters and is undergoing operational tests overseas.
- The Laboratory continues to support the Joint Counter Radio-Controlled IED Electronic Warfare (JCREW) program through the development of architectures and specific technologies for the next generation of counter–improvised explosive device (IED) electronic attack systems. Key risk-reduction activities include field data collections, advanced algorithm development, and hardware development and demonstration.
- Lincoln Laboratory began the development and transition of two airborne sensor systems for use in a quick-reaction intelligence, surveillance, and reconnaissance capability. The first sensor consists of a high-area-rate synthetic aperture radar that is unique in its coverage rate, antenna technology, and real-time target-specific processing. The second sensor uses a novel passive RF detection technology that leverages the Laboratory's innovative detection processing. Both systems will be integrated on an Army aviation asset this year.



Small unmanned systems provide opportunities to supply organic, stand-in sensing capabilities to small units. The Laboratory is working with industry to integrate Laboratory-developed sensors on robots, such as the Packbot pictured above.

Future Outlook

- The Laboratory will continue to add capabilities to the new ACTS II aircraft, which will primarily be used for captive-carry testing of representative electronic attack systems and instrumentation to support the development of advanced U.S. fighter aircraft radars. ACTS II will also carry surrogate infrared sensors and data links used in assessing the capabilities and limitations of beyond-visual-range passive airborne engagements.
- Sidecar systems will be developed for capabilities-based assessments of threat RF systems. A common system architecture will be used to evaluate signal processing and electronic protection upgrades for surveillance, target acquisition, and fire-control radars.
- The current counterterrorism test bed, which supports most of the advanced SIGINT capabilities developed for counter-IED and counterterrorism applications, will be expanded. The enhanced test bed will take on a greater software-defined sensor role and will be used to prototype additional advanced SIGINT capabilities; tagging, tracking, and locating technologies; and advanced radar systems. The flexibility of this test bed is expected to enable the rapid demonstration of new capabilities developed in response to time-critical needs.

The Tactical Systems mission is working with explosives ordnance disposal (EOD) and engineer units to test advanced Force Protection capabilities integrated on the Joint EOD Response Vehicle, pictured here, and other similar vehicles.

HOMELAND PROTECTION

The Homeland Protection mission is supporting the nation's homeland security by developing technology and systems to help prevent terrorist attacks within the United States, to reduce the vulnerability of the United States to terrorism, and to minimize the damage and assist in the recovery from terrorist attacks. Current sponsors for this mission area include the Department of Homeland Security, Department of Defense, and other federal, state, and local entities. Efforts include architecture studies for the defense of civilians and facilities against potential biological attacks, development of the Enhanced Regional Situation Awareness system for air defense of the National Capital Region, development of cyber-security technology for critical homeland infrastructure protection, and the evaluation of technologies for border and maritime security.

Leadership

Dr. Robert T-I. Shin

Dr. Israel Soibelman

Dr. Timothy J. Dasey

The Department of Homeland Security is sponsoring work on the Imaging System for Immersive Surveillance (ISIS). ISIS is a high-resolution, 360° immersive video surveillance system that supports real-time and forensic situational awareness in an urban environment. The ISIS system consists of a custom 240 Mpixel sensor, a multi-terabyte data archive, a multiple-user video interface, and automated video exploitation algorithms. The system can provide 1.2 cm resolution imagery over an area equivalent to ten football fields and can provide video resolution equivalent to that displayed by 120 high-definition televisions.

Principal 2009 Accomplishments

- Lincoln Laboratory continued to support the operation of the Enhanced Regional Situation Awareness (ERSA) system for homeland air defense around the National Capital Region. This support included air security preparations for the Presidential Inauguration in January 2009.
- A successful demonstration of an air surveillance system, built for the Navy and based on the ERSA architecture, was performed in Norfolk, Virginia. This demonstration is a model for the deployment of similar air security systems in the United States.
- Lincoln Laboratory completed a threat assessment and supporting measurements and modeling to establish the feasibility of rapid, in-port shipping container screening for chemical, biological, and explosives materials.
- Multiple test beds were established, specifically in urban areas (Boston and Anaheim, California), to test and evaluate biodetection sensing systems in real-world environments.
- The Lincoln Standoff Aerosol Active Signatures test bed was developed to measure optical properties of biological materials commonly used in standoff sensors.
- An analysis of the current Department of Homeland Security (DHS) air security engagement chain determined the surveillance architecture required for intercepting aircraft before they cross the northern or southwest borders of the United States. Aircraft behaviors in these regions are now being characterized, and algorithms are being explored, to augment this architecture with an automatic threat identification layer.
- In support of the Army and DHS, Lincoln Laboratory developed ground surveillance concepts and site installation plans for wooded, lake, and river environments on the northeast U.S. border. A wide variety of sensor prototypes are being investigated and developed for use on both northeast and southern U.S. borders. The Laboratory is testing the ability of unattended seismic, acoustic, and infrared sensors to detect walkers and vehicles in a wooded border site.
- The Imaging System for Immersive Surveillance (ISIS), a next-generation urban video surveillance system providing tactical and forensic 360° situational awareness, was built for DHS and demonstrated onsite at the Laboratory.
- Lincoln Laboratory established a partnership with CAL FIRE and is pursuing the prototyping of a situational awareness system to support disaster reponse. The demonstration will take place in fall 2009.

A comprehensive study being performed for DHS is addressing the multiple architecture elements needed to improve homeland air security. The resulting technology roadmap will include sensor options for DHS interceptor aircraft.

Lincoln Laboratory performed a tabletop exercise with CAL FIRE to help architect a situational awareness system.

Future Outlook

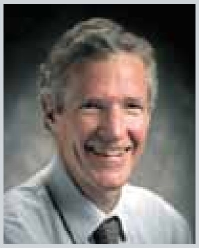
- To demonstrate air security against the evolving air threat, the Laboratory is building new surveillance sensors and creating adaptable decision support tools.
- Over-the-horizon radar and airborne systems are emerging as promising means to achieve an integrated air, land, and maritime surveillance architecture for homeland defense and security. Lincoln Laboratory will lead in-depth modeling and design activities to guide DHS and DoD investment and implementation decisions.
- Rapid high-discrimination biotriggers and low-cost biodetectors will be transitioned to DoD and DHS users.
- The Laboratory will pursue screening concepts at border points of entry for chemical, biological, and explosives hazards.
- The Laboratory will establish and operate test beds that will be used to collect long-term data on chemical, biological, and explosives sensor efficacy.
- The Laboratory is pursuing the design and development of novel active and passive optical techniques that will address both the military and civilian interest in standoff chemical agent early-warning sensing.
- Lincoln Laboratory plans to expand the installation and evaluation of border surveillance sensors, including advanced infrared and low-light imagers and trip wires, ground moving target indication radars, and tunnel intrusion and small unmanned aerial systems.
- Future work on ISIS will include deployment and testing of the system at a major urban airport, as well as the creation of a higher-resolution, 240 Mpixel sensor.
- Lincoln Laboratory will demonstrate a situational awareness system to support disaster response for the state of California.

Lincoln Laboratory is currently testing a variety of unattended sensors that could be used to detect walkers and vehicles in wooded areas along both the northeastern and southern U.S. borders. The above sensor was tested in northern woods under winter conditions.

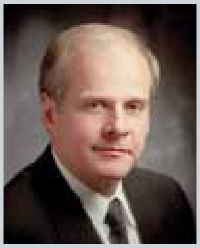
AIR TRAFFIC CONTROL

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 communications. Today, the program has evolved to include a rich set of safety applications, decision support services, and air traffic management automation tools. A focus of the current program is support for the FAA's Next Generation Air Transportation System. 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.

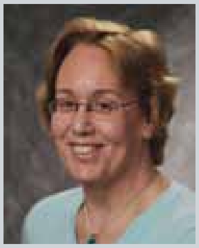
Leadership



Dr. Mark E. Weber



Mr. James M. Flavin



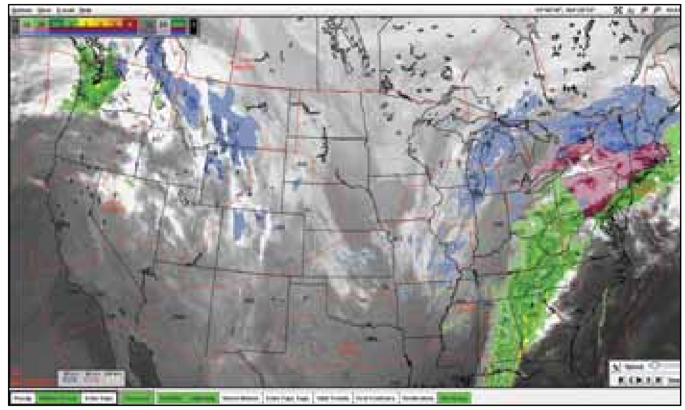
Dr. Marilyn M. Wolfson

Dr. James K. Kuchar

In Lincoln Laboratory's Air Traffic Management (ATM) Laboratory, real-time surveillance, weather, and flight planning data are integrated into a variety of applications that support runway incursion prevention, traffic flow management during adverse weather, and air traffic control tower flight data management. Laboratory researchers use this facility to develop, test, and demonstrate advanced ATM capabilities.

Principal 2009 Accomplishments

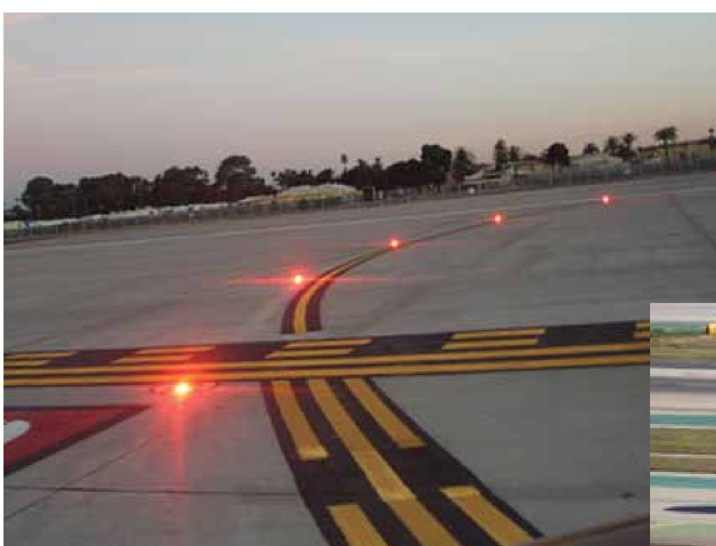
- The Corridor Integrated Weather System (CIWS) has been reengineered to provide continental U.S. coverage and a robust configuration suitable for handoff to the FAA for long-term operation. A prototype six-hour look-ahead thunderstorm forecast system (Consolidated Storm Prediction for Aviation, or CoSPA) is being tested offline in the northeastern U.S. corridor.
- To support the FAA's acquisition of a national Automatic Dependent Surveillance–Broadcast (ADS-B) system, the Laboratory analyzed surveillance requirements and radar/ADS-B fusion algorithms needed for air traffic control (ATC) at key ADS-B sites. This work included the analysis of wide-area multilateration (locating aircraft by computing time difference of arrival of multiple radio signals) as a backup for ADS-B.
- The Laboratory is working with the FAA to refine concepts for a next-generation Multifunction Phased Array Radar (MPAR) that would provide the surveillance services currently acquired from separate ATC and weather radar networks. Current activity is focused on developing and testing active array panels that meet the performance and cost requirements established for MPAR.
- Under development are a Tower Flight Data Manager for future ATC towers and the associated decision support capabilities called the Arrival/Departure Management Tool. This project supports the FAA's Next Generation Air Transportation System (NextGen) through development of the terminal area information exchange architecture, electronic flight data management capability, and integrated arrival/departure and surface traffic management capabilities needed to achieve NextGen goals.
- The Runway Status Lights system continues successful operation at Dallas/Fort Worth International Airport (DFW). A new capability has been added and evaluated at DFW: the Final Approach Runway Occupancy Signal provides warnings to pilots on final approach that the runway ahead is occupied. Runway Entrance Lights and Takeoff Hold Lights have also been installed and evaluated at Los Angeles International Airport. Expansion to Boston Logan International Airport is planned for late 2009.
- Detailed national airspace traffic-density models—as well as detailed trajectory models of noncooperative aircraft, including ultralights, gliders, and balloons—are being used to evaluate sense-and-avoid systems for unmanned aircraft systems for the Department of Defense and Department of Homeland Security.



The Corridor Integrated Weather System was expanded to continental U.S. coverage in 2008, and the winter precipitation depiction and forecast was added in 2009. Greens and yellows indicate precipitation in the form of rain; pinks indicate a mix of rain and snow or ice; and blues indicate all-snow conditions.

Future Outlook

- A major program to develop NextGen air traffic control tower surveillance capabilities, automation platforms, and decision support services will improve safety and efficiency at conventional, on-airport staffed towers and may permit migration of airport ATC services to remote locations at some smaller airports.
- Lincoln Laboratory is assuming an increasingly influential role in the definition and development of the FAA's future System-Wide Information Management architecture that will encompass surveillance, weather, and flight planning/flight event data exchange, decision support applications, and efficient sharing of information amongst decision makers involved in operating the National Airspace System.
- The Laboratory's thunderstorm forecasting capabilities and associated decision support tools will play an increasingly important role in alleviating delays associated with severe weather. The Route Availability Planning Tool, a system designed to expedite departures during convective weather, will be deployed as a prototype to three additional airports and will eventually be incorporated into the FAA's national Traffic Flow Management System.
- Applications are planned for leveraging ADS-B to improve safety, efficiency, and capacity in congested airspace. Lincoln Laboratory will be instrumental in developing the safety case for these applications and in demonstrating their robustness during "off-nominal" conditions (e.g., equipment failures, aircraft noncompliance, adverse weather).
- Increased emphasis is on developing and testing next-generation paradigms for aircraft-separation assurance on the airport surface and during flight. This effort includes evolution of deployed collision-avoidance technologies such as TCAS and Runway Status Lights, as well as simulation, analysis, and robustness testing of future concepts.

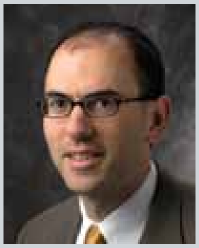


Lincoln Laboratory has supported the FAA in developing and deploying the Runway Status Lights system at the Los Angeles International Airport. The system includes Takeoff Hold Lights and Runway Entrance Lights at key locations to reduce the potential for runway incursions.

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 has been an important contributor to many of the Laboratory's most successful efforts.

Leadership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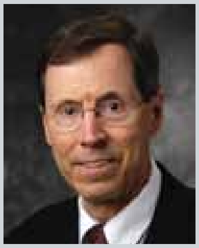
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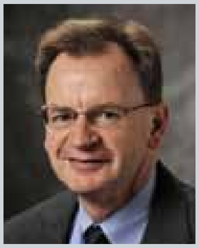
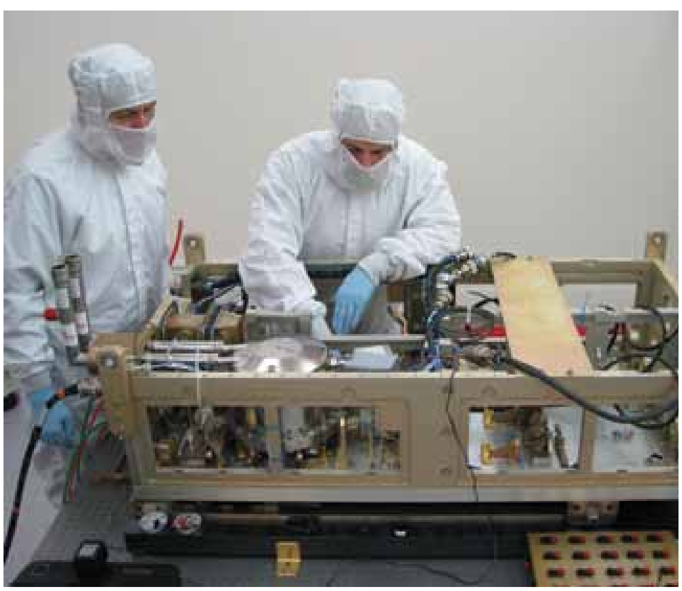

Dr. Michael T. Languirand


Efforts are under way to upgrade the control system and mounts for an optical tracking system.

Principal 2009 Accomplishments

- Lincoln Laboratory undertook major design, fabrication, integration, and test efforts for a diverse portfolio of programs that includes the following:
  - For the Haystack Ultrawideband Satellite Imaging Radar (HUSIR) program, which is developing a large ground-based radar for space surveillance, the Laboratory carried out advanced structural and thermal design and analysis for the antenna that requires an extremely precise surface figure of better than 100 µm over its 120 ft diameter.
  - For an advanced laser system, the Laboratory used 100s of optical elements, a gain medium cooling system, and water-cooled pump lasers in a compact form to meet airborne integration needs.
  - The Lunar Laser Communications Demonstration (LLCD), a system for laser communication from lunar orbit, is using new inertial sensors and control techniques in order to maintain the optical alignment and precision pointing required for optical communication from space.
- The Laboratory significantly enhanced its capabilities in the mechanical design and analysis, fabrication, electronics assembly, integration, and environmental test areas by setting aggressive goals for tracking the number of defects in the fabrication and assembly areas, identifying root causes for failures, and addressing those causes.
- The existing facility used for electronic assembly and inspection was refurbished and equipped with new optical and X-ray inspection instruments. The Laboratory obtained a new vapor phase reflow oven for attaching electronic components to circuit boards by "flowing" the solder in which the components are placed. The new oven provides extremely precise and uniform temperature control in a single stage, allowing much higher-quality solder connections.



Engineers work on installing a gain medium cooling system into the laser module for the upgrade to an advanced laser system.

A project team performs final preparations on an instrumented rocket payload before flight testing.

Future Outlook

- The Laboratory will continue working on diverse hardware projects requiring mechanical design, fabrication, assembly, integration, and environmental test. New efforts currently envisioned include developing spacecraft payloads for laser communication and passive optical sensing, and rapid prototyping for aircraft payloads. The Laboratory will continue to invest in advanced engineering technologies and infrastructure to ensure it has the capabilities to design and develop leading-edge hardware systems.
- The Laboratory's new Rapid Prototyping Group will focus on mechanical design and engineering for rapid prototyping programs. The group will define procedures for using the existing Laboratory design, fabrication, and assembly infrastructure to support efforts requiring hardware delivery within a few months to one year. The group will initially focus on supporting programs in persistent surveillance and counterinsurgency.
- An expanded, Laboratory-centered effort in robotics will focus on helping the DoD evaluate the maturity of existing robotics technologies and their relevance to warfighter applications. Using mature technology, the Laboratory will develop prototype systems to demonstrate current capabilities and will at the same time identify critical technology needs for research and development by the academic community.

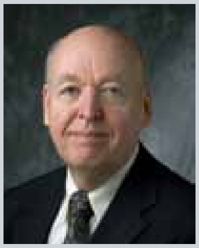
ENERGY

Lincoln Laboratory has a long and rich history in the energy arena. In its earliest days, the Laboratory was involved in satellite power and in distributed systems such as the Semi-Automatic Ground Environment (SAGE). During the "oil crisis" of the 1970s, the Laboratory engaged with the Department of Energy to develop and field solar photovoltaic systems. As the nation and the Department of Defense face new and challenging energy problems, Lincoln Laboratory has committed resources to investigate fundamental energy technology, including thermoelectrics, photovoltaics, electrolysis, high-temperature electronics, biofuels, and process-control software. To reduce deployed military sites' dependence on fossil fuels, the Laboratory is addressing modeling and simulation for alternative energy for sites such as Kwajalein.

Principal 2009 Thrusts

- Lincoln Laboratory has initiated projects to develop analysis, modeling, and simulation tools to analyze renewable energy options for forward-based military sites. These projects are expected to lead to new directions in technology investment and test bed development.
- Working with MIT campus, the Laboratory is developing new thermoelectric (TE) materials and is engineering new TE devices that will provide safe, lightweight power to soldiers in the field.
- In another collaboration with MIT researchers, the Laboratory is pursuing organic photovoltaic (PV) materials, whose purpose is to reduce the manufacturing cost of PV arrays while keeping efficiencies at tolerable levels of 3 to 5%.
- The Laboratory's fully depleted silicon-on-insulator (FDSOI) technology, which is suitable for microelectronics operating in wide temperature extremes (from absolute zero to 300°C), has current applicability to deep well analysis and well logging, and to future projects in geothermal well logging for which boreholes are very deep and very hot.
- In a multiyear project, Lincoln Laboratory is developing systems for detecting errors and vulnerabilities in process-control software for nuclear power plants.
- The Laboratory is exploring bioengineering of algae for biofuel (lipid) production, emphasizing new saccharide pathways in algae. This form of biofuel shows the greatest promise for efficient fuel-oil production with no impact on the food chain.
- Working closely with DoD partners at the U.S. Army Kwajalein Atoll and with the Army's Space and Missile Defense Command, the Laboratory is conducting a detailed study into alternative energy solutions—such as wind, solar, and deep-ocean thermal power for the Reagan Test Site.

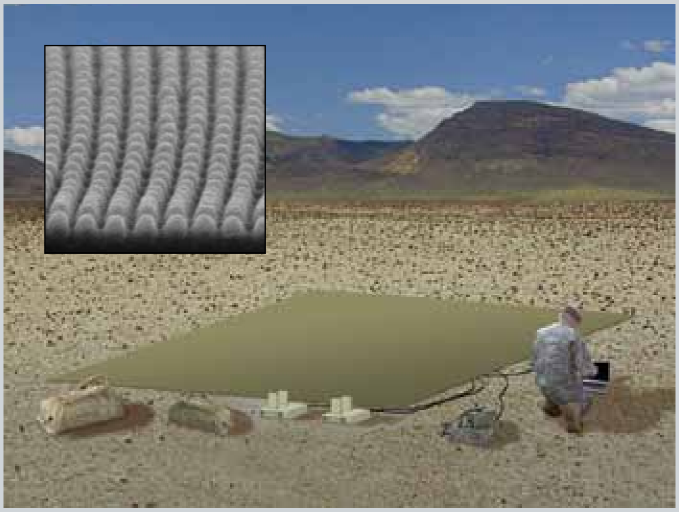
Leadership



Dr. Darryl P. Greenwood

Future Outlook

- Lincoln Laboratory expects to grow its energy program for the DoD, with application to remote sites (forward operating bases). Approaches under investigation include renewable/alternative energy, grid management, innovative solutions, and conservation.
- The Laboratory is applying its meteorological capabilities, developed in support of its Air Traffic Control mission, to the weather issues associated with renewable energy (wind/solar) as well as to severe weather prediction (for improved grid security).
- In exploring ways to reduce peak demands on electricity generation, the Laboratory is studying the use of plug-in hybrid electric vehicles on the micro-grid for load balancing and peak shaving.
- Collaboratively with MIT campus, the Laboratory is working to engineer recent discoveries in the conversion of solar energy into hydrogen fuel, and to do this efficiently, safely, and with application to DoD problems.



Organic-based hybrid cells have the potential to provide cheap, portable kW-scale power to mobile troops and disaster-relief personnel. The inset shows a scanning electron micrograph of a microstructured surface, which enables greater light coupling to the active portions of the device.

WORKSHOPS AND SEMINARS

Lincoln Laboratory hosts annual conferences, workshops, and seminars that bring together members of technical and defense communities to share advancements and ideas, enhance technology development, and provide direction for future research.

High Performance Embedded Computing (HPEC) Workshop – 23–25 September 2008
The HPEC Workshop provided U.S. government-funded researchers from academia, industry, and government an opportunity to discuss the impact of multicore processors on Department of Defense HPEC systems.

Intelligence, Surveillance, and Reconnaissance (ISR) Workshop – 21–23 October 2008
The ISR Workshop is a national forum to present and discuss technology developments and new system concepts in intelligence, surveillance, and reconnaissance.

Project Hercules Program Review – 18–20 November 2008
The Project Hercules Program Review presented the current program in decision algorithm development to the Missile Defense Agency community.

Homeland Protection/Bio-Chem Defense Systems Workshop – 25–26 March 2009
The Homeland Protection/Bio-Chem Defense Systems Workshop presented technological developments in homeland air defense, border security, critical infrastructure protection, disaster management, surveillance and detection of biological and chemical agents, and screening systems.

Defense Technology Seminar (DTS) – 29 March–3 April 2009
DTS 2009 focused on technologies for the warfighter. Major sessions were devoted to missile defense and space situational awareness. New national security challenges in counterinsurgency warfare, homeland security, and network-centric operations were discussed.

Space Control Conference – 5–7 May 2009
The Space Control Conference brought together the space control community to address current capabilities, future needs, and technology development.

Air Vehicle Survivability (AVS) Workshop – 12–14 May 2009
The AVS Workshop presented the air vehicle survivability community with an update on recent analysis and testing, and provided a forum for relevant briefings from the community.

Ballistic Missile Defense (BMD) Joint Advisory Committee (JAC) Meeting – 19–21 May 2009
The BMD JAC Meeting provided the BMD community with an overview of current developments in areas such as missile defense elements, missile defense architectures, advanced concepts and technology, and test infrastructures.

Communications and Networking Workshop – 7–9 July 2009
The Communications and Networking Workshop provided the user, acquisition, research, and developer communities with discussions on lessons learned, current trends, technical challenges, and the road ahead.

Advanced Electronics Technology (AET) Seminar – 15 September 2009
The AET Seminar provided an overview of the solid-state device and electronic subsystems efforts within the Solid State Division. Selected topics were described in more detail within focus talks and poster presentations.

This year marked the thirteenth 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.

ECONOMIC IMPACT AND TECHNOLOGY TRANSFER

The synergistic relationship between MIT Lincoln Laboratory and industry results in a transfer of technology from initial Lincoln Laboratory research and technology development to a commercial industrial production environment initiated by the U.S. Government. The mechanisms for transferring Lincoln Laboratory–developed technology to industry, academia, and government include briefings and technical publications (60 unclassified technical publications were released in the past year); delivery of hardware, software, algorithms, or advanced architecture concepts to government contractors under the auspices of a government sponsor; Small Business Technology Transfer (STTR) projects, which are joint research partnerships with small businesses; and Cooperative Research and Development Agreements (CRADAs), which are privately funded by businesses to transfer the Laboratory's technology.

Lincoln Laboratory technology transfer of hardware, software, algorithms, and advanced architecture concepts to government contractors:

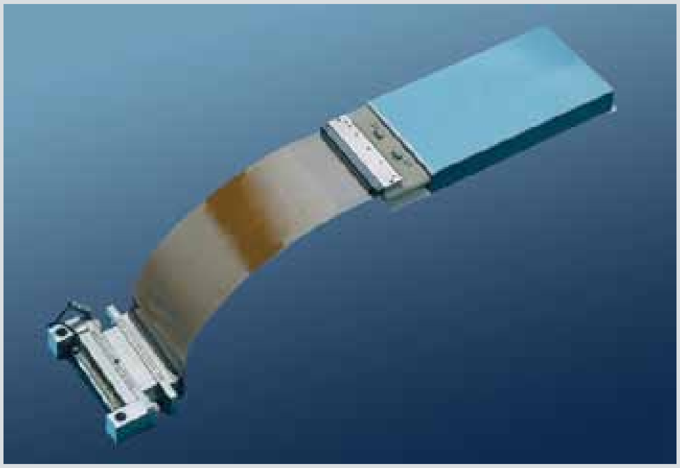
- Lincoln Laboratory's fully depleted silicon-on-insulator (FDSOI) complementary metal-oxide semiconductor (CMOS) process technology has been used by over 60 different U.S. industry, university, and government laboratories to fabricate more than 150 different circuits as part of ten multiproject runs performed in the Microelectronics Laboratory. These multiproject runs exploit the unique attributes of this technology, including low-power operation, high-quality RF performance, and 3-D circuit integration capabilities. This past year, the Laboratory completed its second multiproject run targeted at 3-D circuit integration; 3DM2 allowed researchers from 20 different organizations to explore 3-D circuits for high-performance computing, imaging, and RF applications.
- Lincoln Laboratory's silicon and indium phosphide Geiger-mode avalanche photodiode (APD) technologies were used in Jigsaw and other DARPA and DoD prototype systems. Boeing, BAE, Lockheed Martin, and Northrop Grumman are among the industries using Laboratory-developed APD arrays.
- A spherically curved, 1.2-billion-pixel, ultra-low-noise, orthogonal transfer array, silicon charge-coupled device (CCD) imager was delivered to the Panoramic Survey Telescope and Rapid Response System (Pan-STARRS) operated by the University of Hawaii's Institute for Astronomy. On 6 December 2008, this focal plane began operation on the Pan-STARRS prototype camera.
- Spherically curved, silicon CCD imager technology has been used in the focal-plane arrays for DARPA's Space Surveillance Telescope.
- Also recently transferred to industries, such as Northrop Grumman and Mesosystems, were a low-cost bioaerosol sensor technology and microelectromechanical systems RF switch technology.
- The Laboratory transferred to industry the weather-sensing algorithms for the Terminal Doppler Weather Radar, which is used by air traffic controllers nationwide.

Lincoln Laboratory teamed with small businesses in the following STTR projects:

- Cryogenically cooled Yb:YAG lasers (Q-Peak)
- A sparse-aperture, electronically steered phased array antenna (Applied Radar, Inc.)
- The use of superconducting filters for electromagnetic interference suppression (Out of the Fog Research)
- Evaluations of the nonlinearities of high-temperature superconducting thin films manufactured by two contractors, STI and UES, Inc.

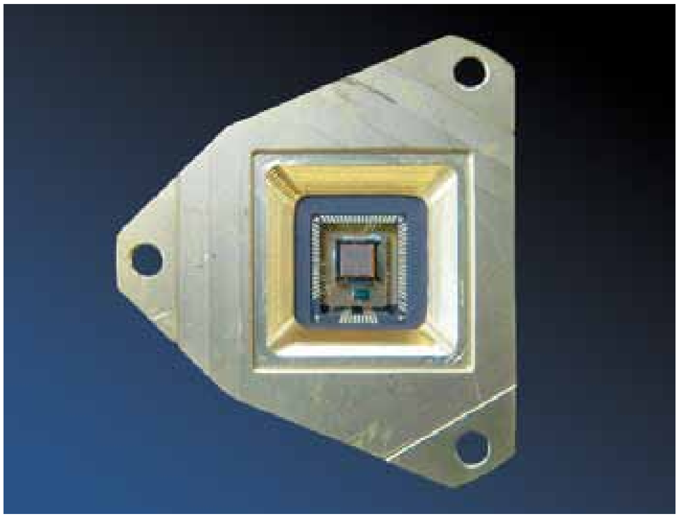
In FY09, CRADAs with local government and business organizations included the following:

- Geosynchronous communication satellite encounter analysis for Telesat, SES Americom, and Satmex
- Biosensor research and development for Innovative Biosensors
- Semiconductor lithography research for Intel, Sematech, and Applied Materials, Inc.
- Thermoelectric materials and device research for BSST

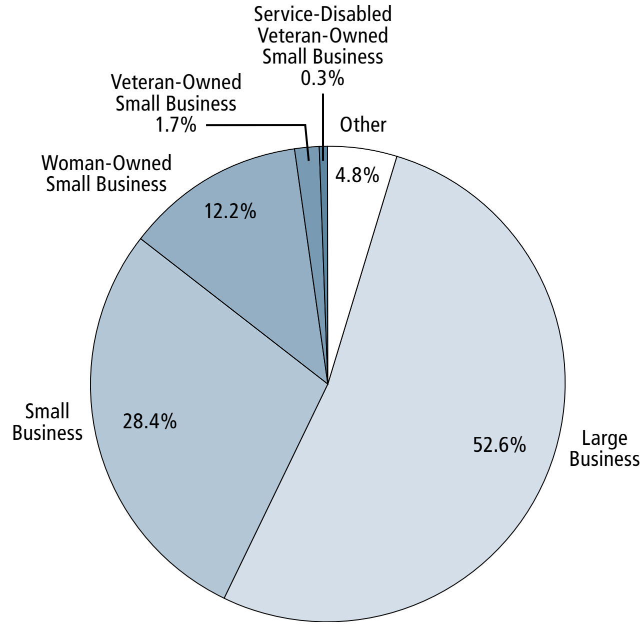


Curved CCD Focal Plane Tiles for DARPA's Space Surveillance Telescope

Space Surveillance Telescope



Avalanche Photodiode Array



Percentage of subcontract expenditures to various categories of business

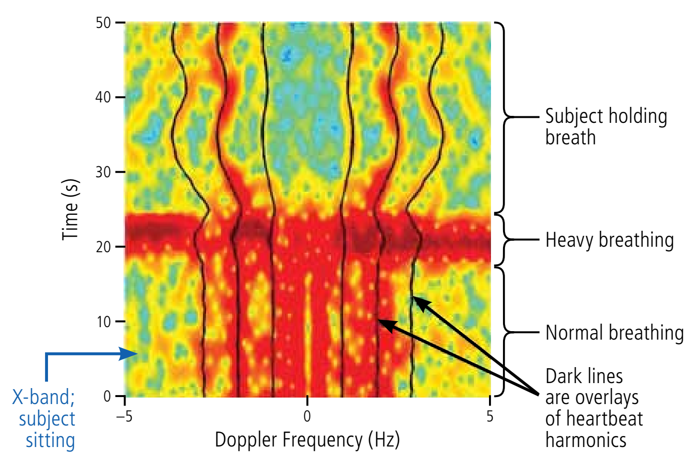
Other direct measures of the Laboratory's contribution to the nation's economy are its history of generating spin-off companies and its success in patenting technology. Since 1951, more than 95 companies have been started by Lincoln Laboratory staff, and 793 U.S. and 250 foreign patents derived from work at Lincoln Laboratory are held by MIT; 359 of these patents have been licensed to industry. In FY08, optical coherence tomography and accordion fringe interferometry license fees totaled $973,000 and $313,000, respectively.

Lincoln Laboratory's partnership with industry includes relationships with universities and with both large and small businesses in the defense and commercial sectors. The Laboratory issues subcontracts for goods and services with a value that exceeds $300 million annually. Small businesses—which supply construction, maintenance, fabrication, and professional technical services in addition to commercial equipment and material—have been primary beneficiaries of the Laboratory's procurement program.

New Technology Initiatives Program

The New Technology Initiatives Program (NTIP) supports initiatives to significantly extend the application of new technologies and approaches to our nation's current and future problems.

The NTIP works with the Laboratory community and outside resources to identify user needs, capability drivers, and enabling technologies. Board members provide leadership to frame a problem space, outline candidate architectures, identify emerging technical capabilities that might apply across the Laboratory, and approve funding for new initiatives. Interdivisional activities and risk-taking are encouraged.



This multicolor plot is X-band radar return data from a human subject seated in an anechoic chamber. These data were collected as part of an NTIP project that is investigating the viability of radar detection of human heartbeat and respiration.

MIT CAMPUS AND LINCOLN LABORATORY COLLABORATIONS

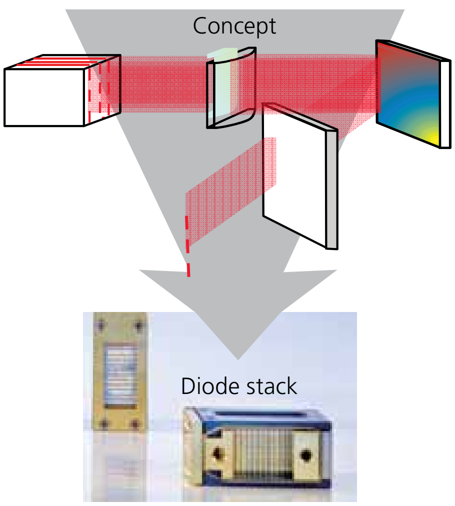
MIT graduate students Ta-Ming Shih (left) and Evelyn Kapusta work in the Laboratory's C-400 cleanroom to fabricate optoelectronic devices and subsystems as part of the Integrated Photonics Initiative.

Integrated Photonics Initiative

The Integrated Photonics Initiative (IPI) is a multiyear, Lincoln Laboratory–funded collaboration between the Laboratory and the MIT campus to support the research of doctoral candidates working on integrated photonic materials, devices, and subsystems.

The IPI's objectives are to identify Department of Defense mission areas that could benefit from integrated photonic technologies, to develop these technologies through graduate research, and to work to insert the technologies into advanced communication and sensor systems. Monthly IPI status meetings, rotating between the Laboratory and the campus, foster interaction between the students, Laboratory staff, and campus faculty. The Laboratory's fabrication facilities and expertise in applied research benefit the students' thesis development.

During the past year, five students focused on such topics as fabrication and test of integrated ultrafast all-optical switches, characterization of the noise and dynamic properties of high-power semiconductor optical amplifiers, development of low-noise semiconductor external-cavity lasers, and investigation of materials for use in integrated optical isolators. This IPI-supported research resulted in three doctoral theses, five conference presentations, and six journal papers, and the students' accomplishments were highlighted at the Annual Meeting of the MIT Center for Integrated Photonic Systems.



Near-ideal beam combining of a commercial laser diode stack was demonstrated in an ACC project investigating a method to increase spatial and spectral brightness of such stacks.

Advanced Concepts Committee

The Lincoln Laboratory Advanced Concepts Committee (ACC) supports the development of innovative concepts that address important technical problems of national interest. The ACC provides seed funding, as well as technical and programmatic support, to investigators with new technology ideas. These ideas are typically high risk, but offer the potential to significantly impact national needs by enabling new systems or improving existing capabilities. Projects are scoped to demonstrate concept feasibility and typically last 9 to 12 months. The ACC encourages collaborative efforts between Lincoln Laboratory and MIT campus.

Recent ACC-sponsored initiatives include research into photon-counting receivers for optical communication; novel nanoparticles that act as optical limiting filters for enhanced eye protection; new assembly techniques that enable higher-quality and higher-power wavelength beam-combined laser diode stacks; and the use of the LLGrid to develop rigorous optical models of light scattering from bioaerosols to enable enhanced algorithms for standoff biodetection.

The ACC also sponsors a Defense Studies Seminar Series that includes speakers associated with the MIT Security Studies Program (SSP). The 2009 seminars included the following:

Fotina Christia, MIT SSP, "Inside Afghan Insurgency: Who Is It That We Are Fighting Against?"

Daryl Press, Dartmouth College, "Oil and U.S. Security: An 'Over the Horizon' Strategy for the Persian Gulf"

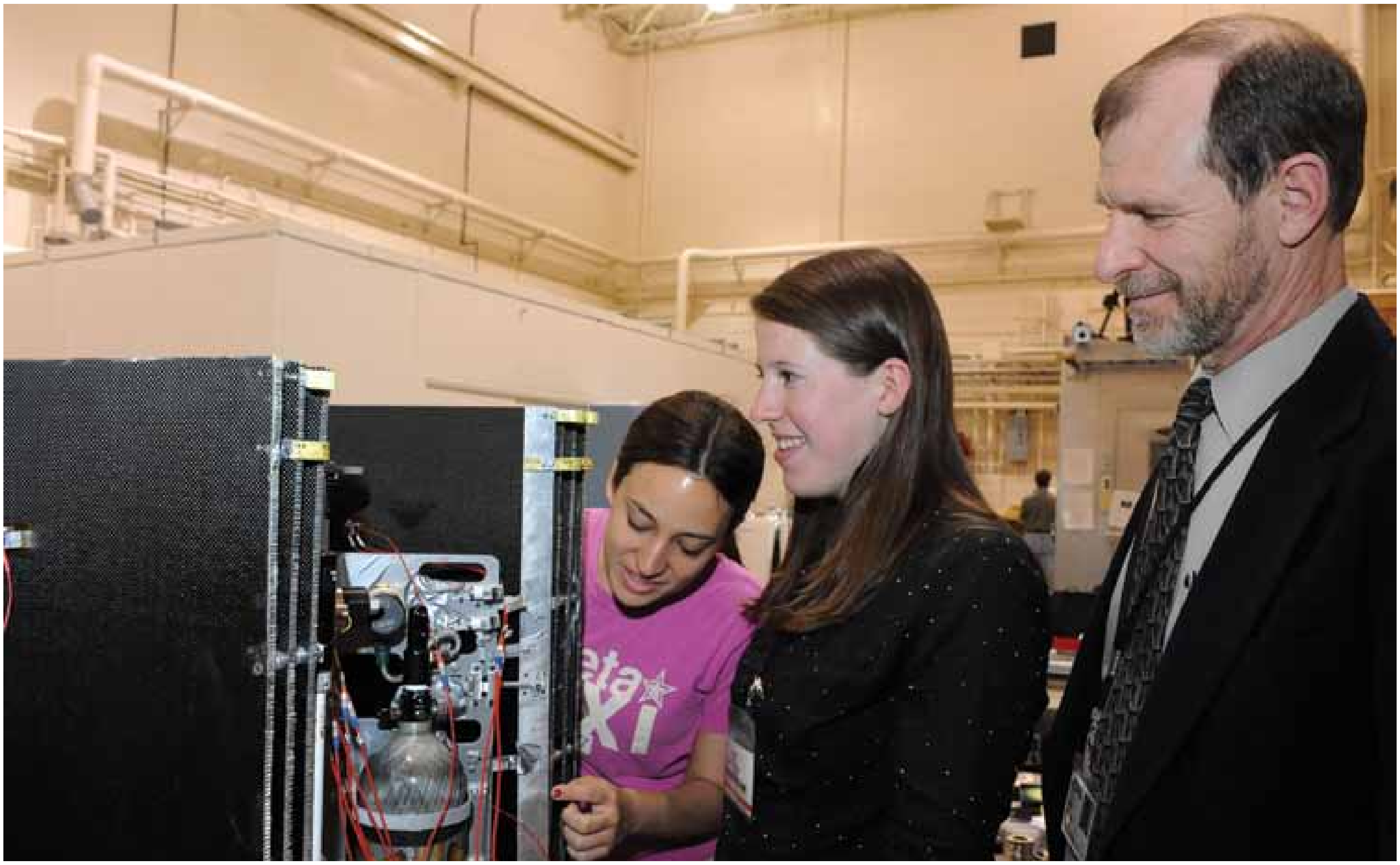
Colin Jackson, Naval War College, "The Result of War is Never Final: Russian Decline and Resurgence"

Decision Modeling Research Initiative

The Decision Modeling Research Initiative (DMRI) is a collaboration between technical staff members at Lincoln Laboratory and MIT's Stochastic Systems Group (SSG). The objective is to make significant contributions to the area of decision modeling. The DMRI is providing a forum for sharing research findings and ideas in order to develop enhanced and scalable sensor fusion, inference, and decision-making algorithms and methodologies. Joint discussions have promoted the transfer of SSG-developed algorithms to Laboratory researchers and in-depth dialogue on challenges of interest to Laboratory programs.

MIT Undergraduate Research Opportunities Program

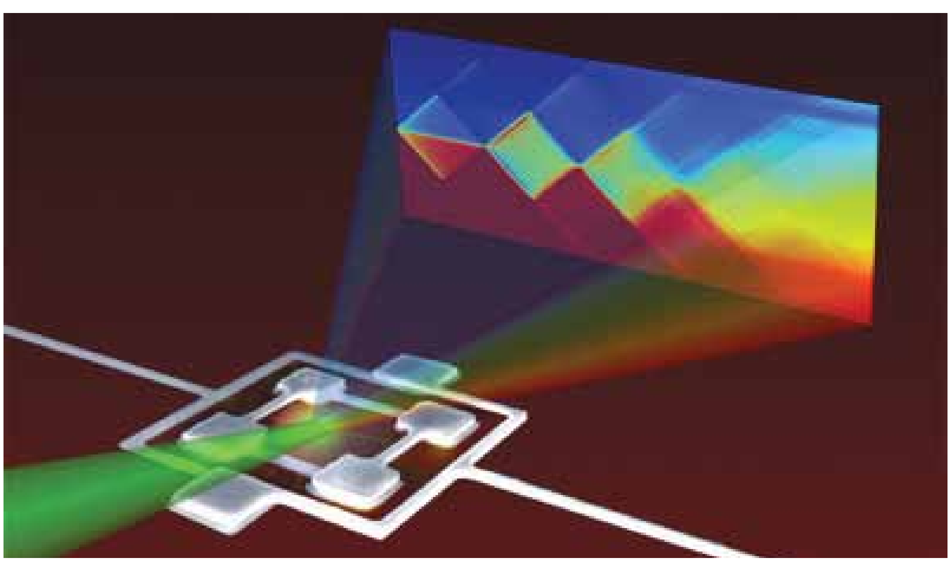
Under the MIT Undergraduate Research Opportunities Program (UROP), Lincoln Laboratory invites undergraduates to participate in onsite research projects. Students develop research plans, write proposals, perform experiments and measurements, analyze data, and present research results. The Laboratory typically hosts five UROP students in the summer and three in the winter.



MIT seniors Frances Gonzalez and Emily Grosse from the Aeronautics and Astronautics Department with mentor John Keesee from Lincoln Laboratory's Space Systems Analysis Group. MIT undergraduate students and two Air Force lieutenants in the graduate program are developing the first student-built satellite with deployable solar arrays. The students shown here at the Laboratory's Environmental Test Laboratory (ETL) are performing both vibration tests and tests on their model in the thermal vacuum chamber. This project is part of a three-semester Space Systems Product Development course at MIT that takes the students through all phases of a hardware project — conception, design, implementation, and operation. When launched, the satellite will demonstrate the performance of a high-efficiency electric engine that could be used to provide maneuverability for satellites on orbit. Lincoln Laboratory technical staff mentor the students on site at the ETL facility and work with Professor David Miller of the Aeronautics and Astronautics Department on campus during the multi-semester course.

Lincoln Laboratory and MIT Seminar Series

The Lincoln Laboratory/MIT Campus Seminar Series is a key element in the Chief Technology Office's continuing endeavors to increase interactions with campus. The Spring Technical Seminar Series at Lincoln Laboratory provides Laboratory staff with the opportunity to engage with leading-edge researchers from the MIT campus. In the past year, the Laboratory hosted five invited talks. A reciprocal Fall Seminar Series on campus provides a forum to extend Lincoln Laboratory's intellectual impact on campus. This past fall, seven talks gave students and faculty an opportunity to hear about ongoing and emerging work at the Laboratory. The topics of these talks included an overview of the Laboratory, Geiger-mode avalanche photodiode array technology, a novel digital infrared focal plane array, quantum computing with superconducting artificial atoms, a bioengineered pathogen detection system, methods to coherently combine laser diodes, and advanced lithography technology.



The diamond-shaped quantum interference patterns, obtained with the new technique of amplitude spectroscopy, form a "fingerprint" of the atomic structure of superconducting qubit artificial atoms. Traditional spectroscopy cannot cover the entire range of energy levels of these artificial atoms, which span the RF and microwave regimes, so the collaboration between Lincoln Laboratory and MIT's Research Laboratory for Electronics conceived and developed the novel analytical technique.

UNIVERSITY INTERACTIONS

University Research Sponsorship

In FY08, MIT Lincoln Laboratory's research contracts with 24 universities were worth almost $9.5 million. These contracts ranged from consulting arrangements with individual professors to university research team efforts. One such effort, MIT/MIT Lincoln Laboratory Integrated Photonics Initiative, includes the development of high-power slab-coupled optical amplifiers, integrated ultrafast optical logic gates, and absorbance modulated optical lithography.

MIT Research Assistants

As part of the research collaboration between MIT campus and Lincoln Laboratory, MIT graduate students are supported as research assistants either on campus or at the Laboratory. Currently, 16 graduate students are working as research assistants on Lincoln Laboratory programs.

Agile Robotics

MIT Lincoln Laboratory is collaborating with the MIT Computer Science and Artificial Intelligence Laboratory (CSAIL) to develop a robotic forklift for military logistics applications. The project, sponsored by the U.S. Army Logistics Innovation Agency, aims to improve the efficiency of U.S. Army supply operations and reduce the number of human operators exposed to harm in warzone storage facilities. Researchers are adapting technology developed for MIT's entry in the DARPA Urban Challenge to enable the forklift's autonomous capabilities.

Lincoln Laboratory is designing components for the vehicle's drive-by-wire conversion and developing algorithms for identifying pallets in the environment from 3-D "point clouds" produced by the laser range sensors. Once the pallet is identified, additional algorithms locate the pallet slots for forklift tine insertion.

Lincoln Laboratory staff also contributed a light detection and ranging (LIDAR) simulator to MIT's existing simulation environment, enabling closed-loop algorithm testing without powering on the forklift. Researchers demonstrated the autonomous forklift's capabilities in April 2009.

Lincoln Laboratory and Northeastern Seminar Series

In 2008, a technical seminar series was established with Northeastern University. During the fall and winter of 2008, eight Lincoln Laboratory technical presentations, on topics such as multifunction civilian air surveillance radar systems and biodefense systems, were hosted by the Electrical and Computer Engineering Department at Northeastern University.

This spring, four seminars by Northeastern professors, speaking on subjects as diverse as integrated three-dimensional carbon nanotube-based nanoelectronics and mobile wireless networks, have been scheduled at the Laboratory. One technical presentation has already led to discussions of the utilization of heterogeneous multiferroic materials for advanced microwave devices.

Lincoln Laboratory and MIT are testing a robotic forklift as part of a joint project for the U.S. Army. The forklift uses sensors developed for MIT's entry in the DARPA Urban Challenge. Eventually, the Army plans to employ the autonomous forklifts to haul materials onto robotic trucks.

TECHNICAL EDUCATION

Seminar for West Point Cadets

During a tour of the Laboratory's Flight and Antenna Test Facility, Stephen McGarry of the Advanced Networks and Applications Group explained to West Point cadets the communications and data collection systems on board the Paul Revere airborne test bed.

Bill Delaney, Director's Office Fellow, talks to West Point cadets about the assembly of components for the upgrade of the Haystack long-range imaging radar to W-band (92–100 GHz).

Ballistic Missile Defense (BMD) Technology Course – 2–4 December 2008

The BMD Technology Course provided an understanding of BMD systems concepts and technologies to military officers and Department of Defense civilians involved in BMD systems development and acquisition.

Networking and Communications Course (NCC) – 5–7 May 2009

Through lectures, demonstrations, and tours, the NCC provides fundamentals and advanced concepts of networks and communications systems for military officers and DoD civilians involved in these, and related, areas of research, development, and acquisition.

Introduction to Radar Systems Course – 16–18 June 2009

This course has been developed to provide an understanding of radar system concepts and technologies to military officers and DoD civilians involved in radar system development, acquisition, and related fields.

Technical Education — Semester-Length Courses

Lincoln Laboratory offers onsite, semester-length courses taught by senior technical staff members or guest lecturers and designed around the following goals:

- Help Laboratory staff maintain and expand their technical knowledge, skills, and effectiveness
- Encourage technical versatility, breadth, and perspective by extending knowledge and understanding across disciplinary and organizational boundaries
- Acquaint newer personnel with the Laboratory's advanced technology and its technical themes

Courses offered in FY09 were Analog Bipolar Circuit Design, Net-Centric Operations, and Signal Processing for Ballistic Missile Defense.

Homeland Security and Counterterrorism Course, Naval War College, Newport, Rhode Island

The Naval War College and MIT Lincoln Laboratory jointly conducted a course exploring the critical technologies, capabilities, operational concepts, and policies that will influence how the U.S. defends its homeland and deals with threats posed by terrorism. Officers from all branches of the Services and the Coast Guard attended seminars on topics that included port and airline security, cruise missile defense, detection of and response to weapons of mass destruction, and critical infrastructure vulnerability.

United States Service Academy Program

Lincoln Laboratory offers internships to both the United States Military Academy (USMA) and the United States Air Force Academy (USAFA) cadets each summer. Last summer, two cadets from the USMA at West Point worked on the Family of Advanced Beyond-line-of-sight Terminals (FAB-T) Program. One USAFA cadet developed the test plan and test cards in support of the Army's annual Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR) Experiment at Fort Dix, New Jersey. Another USAFA cadet developed algorithms used in testing lasercom terminals.

STUDENT PROGRAMS

Lincoln Laboratory participates in a variety of programs through which students gain research experience or investigate careers in engineering, technology, science, or math. Under some programs, students fulfill an academic requirement, while other programs support thesis work at specific universities or offer paid internships at the Laboratory. Often, a student's experience at the Laboratory evolves into post-graduation employment.

Summer Research Program

Lincoln Laboratory offers undergraduate and graduate students the unique opportunity to gain hands-on experience in a leading-edge research environment. Program participants contribute to projects and gain experience that complements their courses of study. Opportunities exist in fields such as communications systems, sensor and radar data analysis, digital signal processing, laser and electro-optical systems, solid-state electronics, software engineering, and scientific programming. During the summer, the Laboratory hires, on average, approximately 100 students from top universities.

University Cooperative Education Students

Technical groups at Lincoln Laboratory employ students from MIT, Northeastern University, and other area colleges as co-ops working full time with mentors during the summer or work/study semesters and part time during academic terms. Co-ops participate in building prototypes, help solve problems, assist in research activities, and test applications in the field. Highly qualified students selected as co-ops become significant contributors to Lincoln Laboratory project teams and often are invited to return for subsequent internships.

MIT VI-A Master of Engineering Thesis Program

Lincoln Laboratory is an industry partner of MIT's Department of Electrical Engineering and Computer Science VI-A Master of Engineering (MEng) Thesis Program, which matches industry mentors with undergraduate students who have demonstrated excellent academic preparation and motivation. The VI-A students selected to work at Lincoln Laboratory acquire experience in testing, design, development, research, programming, and project planning. Students in the VI-A program spend two summers as paid interns, participating in projects related to their fields. Then, the students are supported for one or two semesters as research assistants while they complete their Lincoln Laboratory–specific MEng theses under the supervision of both Laboratory engineers and MIT faculty.

WPI Major Qualifying Project Program

Lincoln Laboratory collaborates with Worcester Polytechnic Institute (WPI) in its Major Qualifying Project (MQP) program, which requires students to complete an undergraduate project equivalent to a senior thesis. The MQP demonstrates the application of skills, methods, and knowledge to the solution of a problem representative of the type encountered in industry. Seven students have successfully completed their projects at Lincoln Laboratory in the past year.

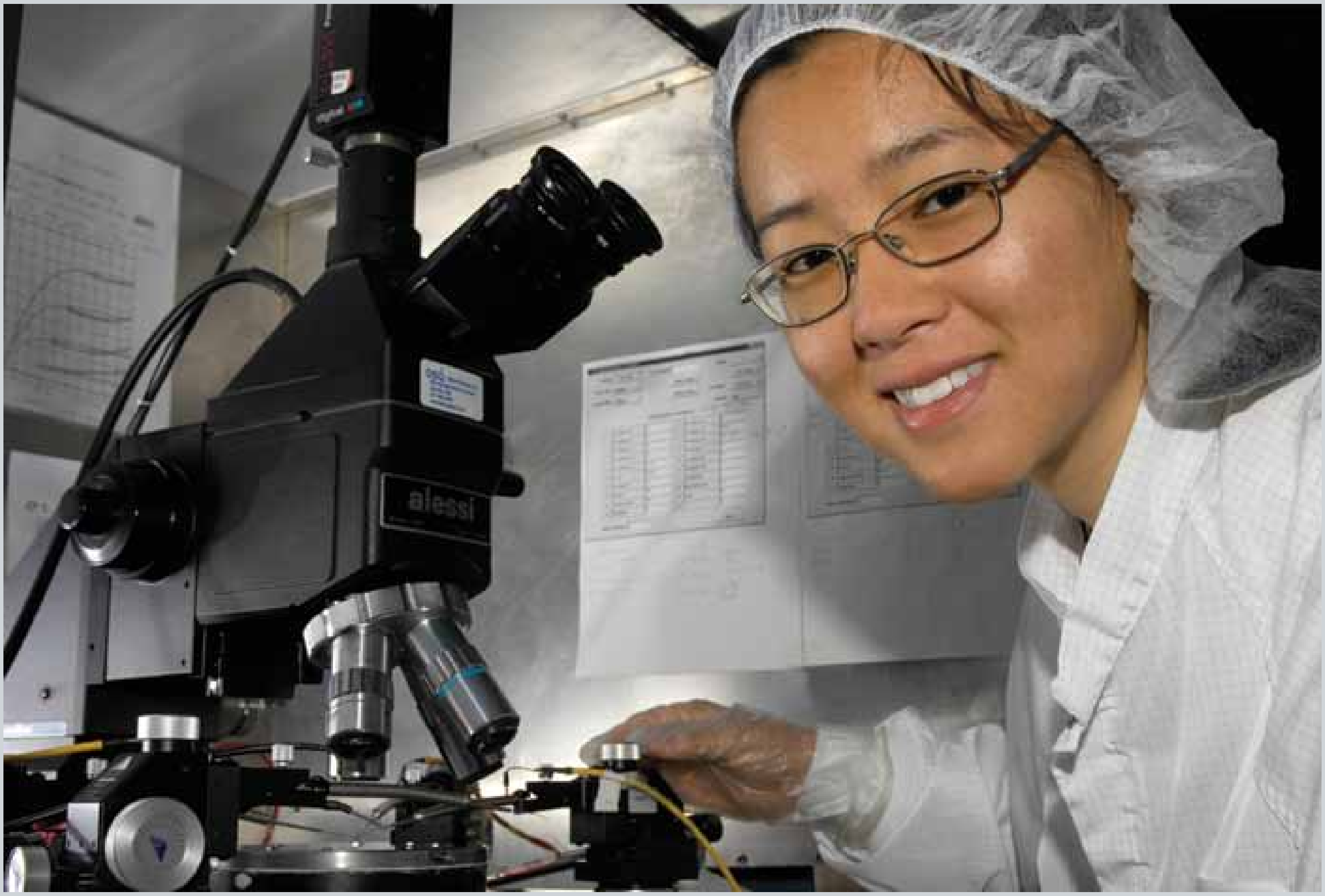
Graduate Fellowship Program

Lincoln Laboratory offers a limited number of graduate fellowships to science and engineering students pursuing MS or PhD degrees at partner universities. The fellowship program awards funds to support a Fellow's stipend, supplement a graduate assistantship, or subsidize other direct research expenses during the final phases of students' thesis research. The Laboratory began this program in 2002 in collaboration with five schools. Today, the program includes eleven schools: The Ohio State University, Brigham Young University, Washington University–St. Louis, Clemson University, University of Michigan, North Carolina State University, University of Washington, New Mexico State University, University of Illinois, University of Colorado, and MIT.

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. 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. The participating schools are Bryn Mawr College, Howard University, Mount Holyoke College, New Mexico State University, North Carolina Agricultural and Technical State University, Smith College, Spelman College, Stevens Institute of Technology, the University of Puerto Rico at Malagüez, and Wellesley College.

MIT VI-A MASTER OF ENGINEERING THESIS PROGRAM



Pei-Lan Hsu, an MIT VI-A Master of Engineering student working in the Advanced Silicon Technology Group, explored the properties of graphene transistors to determine their use as replacements for silicon devices in electronics technologies.

Nivedita Chandrasekaran works in the Mars Lab as part of the research for her MIT Master of Engineering thesis.

Lincoln Laboratory has for many years developed technical talent through the MIT VI-A Master of Engineering Thesis Program. Pei-Lan Hsu worked on her thesis research at Lincoln Laboratory for three consecutive summers. She credits her internship with giving her hands-on experience and field-specific practice in microelectronics.

MIT VI-A students consider the program at Lincoln Laboratory exceptionally strong. Nivedita Chandrasekaran, who works in the Advanced Space Systems and Concepts Group while completing her thesis, feels Lincoln Laboratory is the best place for an internship: "The Lab provides the rare combination of a research institution geared toward producing physical implementations of cutting-edge theoretical research performed at a lab. As a result, a VI-A student gets the best of both worlds, academia and industry."

Working at Lincoln Laboratory helped Nivedita learn to participate successfully as a team member on a large project. She says, "This experience has been particularly valuable because I learned how to own my part of a project as well as how to integrate my portion with the rest of a large complicated system to create a final, exciting product."

AWARDS AND RECOGNITION

Air Force Meritorious Civilian Service Award
Dr. Grant H. Stokes, for his service on the Air Force Scientific Advisory Board.

Secretary of Defense Medal for Outstanding Public Service
Dr. R. Louis Bellaire, for exceptionally outstanding public service as the Sensors Directorate Chief Engineer and Acting Technical Director, Deputy for Test Integration and Fielding, Missile Defense Agency, from September 2006 to February 2008.

Lincoln Laboratory Technical Excellence Awards
Allen D. Pillsbury, for innovation in the mechanical design of space-based sensors and optical communication systems. Mr. Pillsbury has led engineering efforts to introduce new technologies that demonstrate revolutionary performance gains for space systems.

Dr. Benny J. Sheeks, for his analysis of radar observations of foreign and domestic ballistic missiles. Dr. Sheeks is the pre-eminent national expert in the utilization and interpretation of real-world ballistic missile radar data. His techniques and results have formed a critical cornerstone for the development of the Ballistic Missile Defense System.

2009 IEEE Fellows
Dr. Michael S. Brandstein, for contributions to microphone array signal processing for speech and multimedia applications.

Dr. Darryl P. Greenwood, for contributions to the design and performance of adaptive optical systems.

2009 NOAA–David Johnson Award
Dr. William J. Blackwell, for outstanding innovative use of Earth-observation satellite data.

2009 Optical Society of America Fellow
Dr. John J. Zayhowski, for seminal contributions in miniature solid-state laser technology and laser applications and for pioneering work on microchip lasers.

2008 NASA Group Achievement Award
For exemplary participation in the 2006 Joint Flight Demonstration: **Dr. Kevin Cohen, Victor Cyrkler, Mehul Dhorajia, Allyn Dullighan, James Dunn, Kenneth Gregson, Kevin Johnson, Danial Lane, Charles Magnarelli, Robert Maynard, Bonnie McKowen, Lance Michael, Walter Moquin, James Morrissey, Robert Murray, Dr. Eliahu Niewood, Albert Theriault, Dr. James Truitt,** and **David Ventura.**

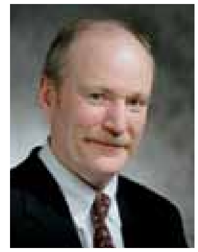
2007 Paul F. Holloway Non-Aerospace Technology Transfer Award
Dr. Marilyn M. Wolfson, Dr. Haig Iskenderian, and **Earle R. Williams** for outstanding contributions to the development of new technology and significant participation in technology transfer activities.

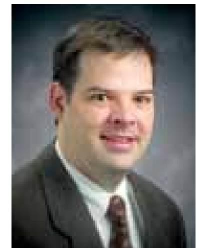
Air Traffic Association Technical Writing Award
Dr. Marilyn M. Wolfson and **Dr. James E. Evans,** First Place Technical Writing Award for a journal article on technology for air traffic management.

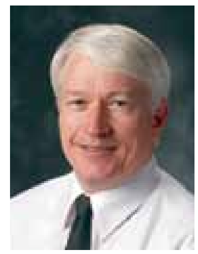
2009 IEEE Aerospace Conference Best Paper Award
Dr. Clifford J. Weinstein, Dr. William M. Campbell, Dr. Brian W. Delaney, and **Gerald C. O'Leary** of the Information Systems Technology Group received the award for excellence in technical innovation and presentation demonstrated by their paper *Modeling and Detection Techniques for Counter-Terror Social Network Analysis and Intent Recognition.*

2009 MIT Excellence Awards
Creating Connections Award: **Joanne Knoll,** Intelligence, Test, and Evaluation Group
Serving the Client Award: **Andrea E. Lamberti,** Intelligence, Test, and Evaluation Group
Innovative Solutions Award: **Dr. Carl H. Fischer,** Sensor Technology and System Applications Group
Unsung Hero Award: **Antonio S. Ruscitti,** Sensor Technology and System Applications Group

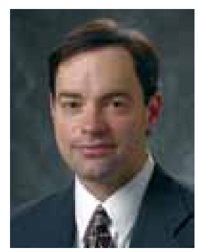
2008 "Superior" Security Rating
To Lincoln Laboratory's collateral security program from the Commander of the 66th Security Forces Squadron at Hanscom Air Force Base.

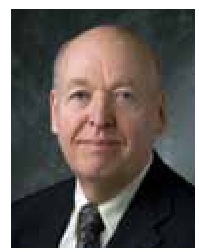

Dr. Grant H. Stokes

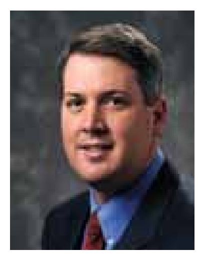

Dr. R. Louis Bellaire

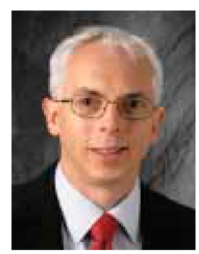

Allen D. Pillsbury


Dr. Benny J. Sheeks


Dr. Michael S. Brandstein


Dr. Darryl P. Greenwood


Dr. William J. Blackwell


Dr. John J. Zayhowski

ROLL: Robotics Outreach at Lincoln Laboratory

In its second year, Robotics Outreach at Lincoln Laboratory (ROLL) continued to provide successful experiences for young people. Last summer and fall, ROLL hosted two Weekend Robotics Workshops—two-day, full-immersion programs in which high-school students learned and tested robotic programming sequences using Lego Mindstorm robots.

ROLL also sponsored four teams, in age groups ranging from 9- to 18-year-olds, at the For Inspiration and Recognition of Science and Technology (FIRST) Robotics competitions. Volunteers mentored students at weekly sessions that covered programming robots to complete challenges specified by FIRST. The teams performed well in regional competitions that began in November 2008. The Lincoln Laboratory team of 13- and 14-year-olds was ranked second out of 64 teams and won the award for robot performance.

At a state-wide tournament, the team of 15- to 18-year-olds received special recognition for technical strength and professionalism, and won first place, qualifying them to compete in the 2009 FIRST Technical Challenge (FTC) World Championship in April, where they achieved 24th place out of the 100 teams at the Finals in Atlanta, and the 985 teams registered this year.

ROLL forged into new territory when a local elementary school requested help in teaching first- and second-grade students the concepts of programming and robotics.

ROLL mentor Greg Surbey helps a participant test his program for sensing and following a curved black line.

ROLL mentors developed several role-playing games that required one or more students to be the robot(s) and follow specific instructions from other students playing the part of programmers who supplied those instructions one step at a time. The activity introduced the concept of "looping," a programming term for a sequence of instructions that is continually repeated until a certain condition is reached.

ROLL was established to foster in students a curiosity about and a sense of accomplishment in science, technology, engineering, and mathematics by engaging them in hands-on robotics activities.

Participants at a Weekend Robotics Workshop evaluated their programming skills by testing their robots' ability to perform tasks such as navigating a maze and avoiding a blocked path.

MIT Lincoln Laboratory's FTC team, MITiBOT, placed in the semifinals in the World Championship. Lincoln Laboratory mentors John Peabody and Brian Shucker sit in the top row.

COMMUNITY OUTREACH

Community Service and Giving

The Lincoln Laboratory "Hike and Bike the Berkshires" team raised over $10,000 for the National Multiple Sclerosis (MS) Society.

Multiple Sclerosis Hike and Bike Event

As part of the Lincoln Laboratory Community Outreach (LLCO) efforts, Laboratory staff participate in the National Multiple Sclerosis (MS) Society's "Hike and Bike the Berkshires" event. This year, LLCO hiking and cycling teams totaled 19 members and raised more than $10,000 for the MS Society.

Used-Book Drive and Sale

In coordination with the MIT Community Giving Fund, Lincoln Laboratory raised over $2,850 at a February used-book drive and sale.

Support Our Troops Drive

Lincoln Laboratory runs an ongoing campaign of support for deployed U.S. troops. Donations of food, toiletries, books, and games are collected daily, boxed by volunteers, and mailed weekly. Since October 2008, Support Our Troops has sent 162 packages to 26 troops. This effort was expanded in 2008 to include the collection of warm coats and shoes for children of an Iraqi village where U.S. Marines are stationed; 32 boxes of coats and shoes were sent to Iraq. In addition, 17 care packages were mailed to a children's aid program run by U.S. troops in Afghanistan.

Educational Outreach

Science on Saturday

This program features onsite science demonstrations by Lincoln Laboratory technical staff. More than 2500 local K–12 students, their parents, and teachers have enjoyed demonstrations on rockets, robotics, asteroids, archaeology, optics and lasers, and polymers.

Classroom Presentations

Dr. Todd Rider coordinates a program that sends technical staff members to local schools, giving presentations to students in grades K–12. More than 6000 students have enjoyed presentations on cryogenics, electronic circuits, paleontology, biotechnology, astrophysics, and other topics.

AFCEA International Program

Lincoln Laboratory participates in the Armed Forces Communications and Electronics Association (AFCEA) International Program. AFCEA provides educational incentives and assistance for high-school students engaged in information management, communications, and intelligence efforts while fostering excellence in science. Lincoln Laboratory employed three AFCEA students this year.

Robotics Outreach at Lincoln Laboratory

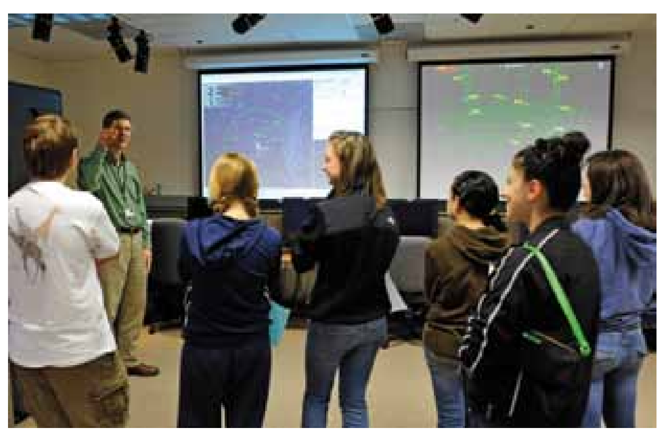
In 2008, Lincoln Laboratory established a Robotics Initiative—a new educational outreach program designed to stimulate youth interest in science and technology. A part of this program, Robotics Outreach at Lincoln Laboratory (ROLL), seeks to foster a sense of excitement that might drive students towards math, science, and engineering by engaging them in robotics and workshops.

Dr. Richard Williamson demonstrates the properties and science of liquid nitrogen in an interactive presentation to a Cub Scout pack in Sudbury, Massachusetts.

Education and Community Service

In a demonstration on safely building a rocket, a Lincoln Laboratory scientist increased the amount of water (weight) added to a model rocket until the rocket "blasted off" to the ceiling.

Chaplain Brandon Harding, 1st BN 3D Marines, H&S Company, sent a letter to Lincoln Laboratory Community Outreach requesting donations of shoes and coats for the children of Iraq.



During a tour for high-school students, a technical staff member explained the technology the Laboratory developed to provide air traffic controllers with up-to-date weather information and the Runway Status Lights system developed for the FAA to prevent runway collisions.

MIT LINCOLN LABORATORY ORGANIZATIONAL CHART

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Head

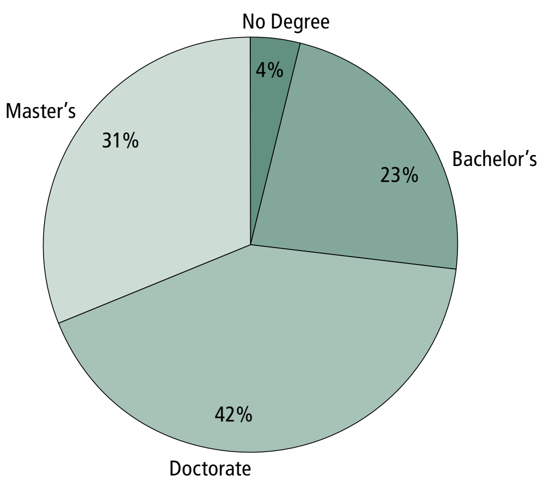
Lawrence M. Candell
Assistant Head

Craig E. Perini
Assistant Head

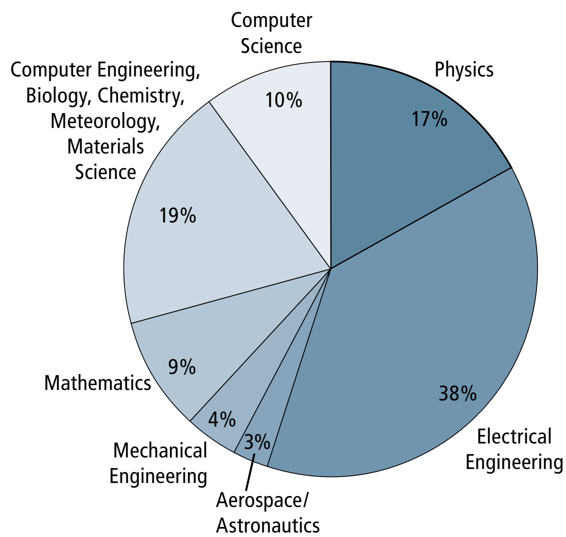
COMPOSITION OF PROFESSIONAL STAFF

Staff Technical Equivalents:	1,411
Support:	961
Technical Support:	301
Subcontractors:	506
Total Employees:	3,179

by Degree

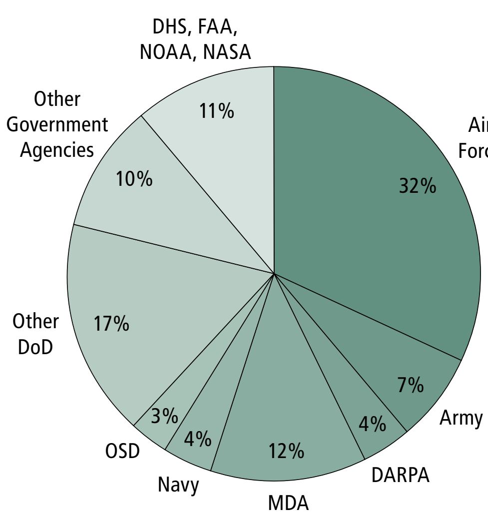


by Academic Discipline

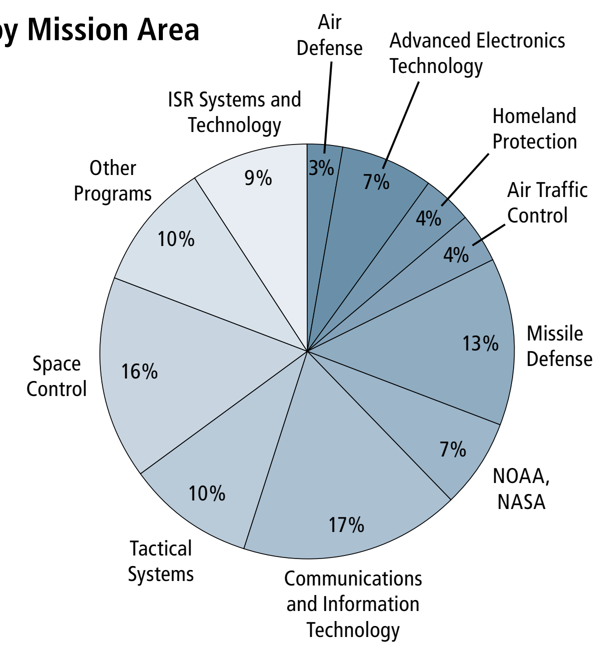


LABORATORY PROGRAMS

by Sponsor



by Mission Area



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OFFICE OF THE PROVOST

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Provost

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

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

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President of the Association
of the U.S. Army,
Former Chief of Staff of the U.S. Army

Lincoln Space Surveillance Complex, Westford, Massachusetts

Reagan Test Site, Kwajalein Atoll, Marshall Islands

Technology in Support of National Security

LINCOLN LABORATORY
Massachusetts Institute of Technology
244 Wood Street, Lexington, MA 02420-9108

www.ll.mit.edu

Contact:
Communications Office
781-981-4204

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