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R&D 100
Awards

66
MIT LINCOLN LABORATORY
technologies recognized as among the best innovations of each year, 2010–2020

Technology in Support of National Security

www.ll.mit.edu
Technology in Support of National Security

MIT Lincoln Laboratory researches and develops a broad array of advanced technologies to meet critical national security needs. What sets us apart from many national R&D laboratories is our focus on building operational prototypes of the unique systems we design.

Our ability to turn concepts into field-worthy systems is supported by state-of-the-art facilities, such as a world-class semiconductor research and fabrication laboratory, a flight facility with aircraft customized for field-testing airborne systems, and New England’s fastest, most powerful supercomputing center.

Behind our innovative R&D are people with exceptional technical abilities and creativity, working in cross-disciplinary teams to develop advanced technologies for diverse needs — for example, defending against missile threats, providing secure communications, monitoring activity in space, and even inventing biomedical devices.

Quick Facts

MIT Lincoln Laboratory is a Department of Defense federally funded research and development center

Established
1951

Location
Lexington, Massachusetts

Research areas
- Sensor systems
- Communications
- Artificial intelligence
- Cybersecurity
- Data analytics
- Microelectronics
- Biotechnology
- Air and missile defense
- Space systems

www.ll.mit.edu
Letter from the Director

Each year, R&D 100 Awards are awarded to the 100 most innovative technologies transitioned during the year for use in real systems or applications. The awards are selected by a panel of technical editors and subject-matter experts, and they represent a cross section of work from across the research and development community. The awards recognize diverse products developed by industry, research laboratories, and academic institutions worldwide. MIT Lincoln Laboratory is honored to have been selected for 66 of these awards over the past 11 years.

Our recognized technologies reflect the wide range of research and development in which Lincoln Laboratory is engaged across our mission areas. Some of the winners come from our long-standing work on radar technology and air traffic control systems while others come from newer fields, such as microbiome testing and quantum sensing. Many of the technologies began as projects supported by funding from the Under Secretary of Defense for Research and Engineering for investigations into new technology that supports important, new defense capabilities.

This booklet was produced not only to recognize our award-winning technologies but to applaud the work of the teams behind each of these awardees. These teams put their technical expertise into developing some of the world’s most significant technologies. Some of the teams collaborated with sponsoring agencies, academic partners, and industry. Many of these teams worked with dozens of contributors for several years to mature their technologies for transition to real systems. These projects represent the commitment of the entire Lincoln Laboratory to technical excellence in support of national security.

Eric D. Evans
Director

Principal investigators of Lincoln Laboratory’s 2019 R&D 100 Award-winning technologies. As a precaution motivated by the COVID-19 pandemic, the 2020 R&D 100 Award recipients were recognized in virtual events held in November.
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Cyber Sensing for Power Outage Detection
A system that uses data on internet traffic to rapidly estimate and map the extent and location of power outages across geographic boundaries.

Defensive Wire Routing for Untrusted Integrated Circuit Fabrication
Techniques that deter an outsourced foundry from maliciously tampering with or modifying the security-critical components of a digital circuit design.

Keylime
An open-source key bootstrapping and integrity management software architecture that is designed to increase the security and privacy of Edge, Cloud, and Internet of Things (IoT) devices.

Forensic Video Exploitation and Analysis
A suite of tools that enables users to efficiently analyze video captured by existing large-scale closed-circuit television systems.
A technique that injects numerous bugs into a program at known locations and constructs triggering inputs for each to create ground truth for evaluating bug-finding systems.

CODEVELOPERS: STAFF FROM NEW YORK UNIVERSITY, NORTHEASTERN UNIVERSITY, AND THE U.S. ARMY

Reconnaissance of Influence Operations

A software system that automates the detection of disinformation narratives, networks, and influential actors to address the growing threat posed by adversaries using social media for political objectives.

CODEVELOPERS: STAFF FROM HARVARD UNIVERSITY

TeraByte InfraRed Delivery

An optical communications technology that enables error-free transmission of data from low Earth–orbiting satellites at a rate of 200 gigabits per second.

Timely Randomization Applied to Commodity Executables at Runtime

A technique that protects Windows applications against cyber attacks by automatically and transparently re-randomizing the applications’ sensitive internal data and layout every time an output is generated.

2020 WINNER
Aperture Level Simultaneous Transmit and Receive Phased Array

The first-ever demonstration of a phased array antenna system that has sufficient isolation to enable practical multi-beam full-duplex communication.

Dual-Mode Imaging Receiver

A camera that integrates the previously disparate functions of high-frame-rate photon-counting imaging and single-photon-sensitive communications into a single optical receiver.

ArtGut

The first in vitro platform that enables researchers to perform high-resolution, physiologically relevant gut microbiome studies.
Gas Mapping LiDAR™
A sensor, built by Bridger Photonics and enabled by Lincoln Laboratory’s slab-coupled optical waveguide amplifier (SCOWA), that remotely detects, locates, and quantifies methane leaks and oil and gas infrastructure status.

CODEVELOPERS: STAFF FROM BRIDGER PHOTONICS

Lightweight Deployable Array Panels for Space
Panels for space-based communications and remote sensing systems that have minimized weight and size to lower launch costs by reducing fuel needs and increasing capacity to accommodate more systems per launch.

Rapid Convective Growth Detector
A system that uses tilt-by-tilt processing of weather radar data to identify and display regions of hazardous storm growth 10 times faster than other weather sensors.

CODEVELOPERS: STAFF FROM THE FEDERAL AVIATION ADMINISTRATION

Mobility and Biomechanics Insert for Load Evaluation
Biomechanical sensors that are built into a shoe insert and small ankle package to measure a user’s weight and lower leg movements to help guide decisions about load-bearing and gait.
**An architecture that was developed by a Department of Defense-led consortium of government, industry, and academic partners to provide an interoperability standard for highly modular, resilient, scalable, and mission-specific microgrid solutions.**

**CODEVELOPERS:** STAFF FROM HG ENGINEERING, PARSONS, SCHWEITZER ENGINEERING LABS, U.S. ARMY, AND U.S. MARINE CORPS

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**Targeted Acoustic Laser Communication**

A system that uses laser photoacoustics to create audible messages in a person’s ear, enabling secure and remote communications with the individual of interest and no one else.

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**Visibility Estimation through Image Analytics**

A software system, developed by the Laboratory in partnership with the Federal Aviation Administration, that provides air traffic managers and pilots with an inexpensive, yet effective, way to automatically extract from camera images vital data about meteorological visibility.

**CODEVELOPERS:** STAFF FROM THE FEDERAL AVIATION ADMINISTRATION

---

**Image capture**

**Edge detection**

10+ miles

Quarter mile
Dynamic Flow Isolation
A technique that reduces unauthorized access to networks by restricting user privileges to only the computer resources users need.

Human-Machine Collaborative Optimization via Apprenticeship Scheduling
A machine learning algorithm that provides real-time decision support by applying heuristics learned from the observed behavior of human experts.

Web-Based HURREVAC
An open-source decision support platform that enables emergency managers to plan, train for, and make accurate hurricane evacuation decisions.
Immersive Imaging System
A wide-area video surveillance system that provides very high-resolution images and 360-degree coverage from a single vantage point.

Intelligent Power Distribution
An electrical box that improves the efficiency and resiliency of microgrids operating in austere conditions by coordinating the microgrid’s energy resources and loads.

Multirate Differential Phase Shift Keying Optical Communications
A format that enables efficient free-space laser communications over a wide range of data rates by using a single easy-to-implement transmitter and receiver design.

Peregrine: Network Navigation
A system of networked deployable devices, powered by cooperative algorithms, that enables highly accurate navigation in environments where GPS is not available, reliable, or precise.
CODEVELOPERS: RESEARCHERS FROM MIT
Photonic Lantern Adaptive Spatial Mode Control
A technology that provides the ability to steer and shape a laser beam, as well as scale its power, in the presence of optical disturbances and turbulence

Ultrafast Computational Methods for Searching DNA Databases
Algorithms that drastically reduce the compute time required to compare a large number of unknown DNA profiles against a large dataset of millions of reference DNA profiles

Very Large-Scale Integration Process for Superconducting Electronics
A fabrication process that taps into superconductivity to provide fast, energy-efficient integrated circuits for advanced computing, digital signal processing, quantum metrology, and sensing
2017 WINNER

Ground-Based Sense-and-Avoid System for Unmanned Aircraft Systems

A first-in-production ground radar system that enables unmanned aircraft to see and avoid other aircraft

CODEVELOPERS: STAFF FROM THE U.S. ARMY, SRC INC., AND KUTTA TECHNOLOGIES

2017 WINNER

CO₂/O₂ Breath and Respiration Analyzer

A wireless, low-cost sensor that determines from a person's breath the fraction of metabolic energy produced by carbohydrate versus fat oxidation, providing information to guide weight loss and training

CODEVELOPERS: STAFF FROM THE U.S. ARMY RESEARCH INSTITUTE OF ENVIRONMENTAL MEDICINE

2017 WINNER

Polarimetric Co-location Layering

A novel algorithm that leverages polarimetry in maritime radar to mitigate the high false-alarm rate caused by radar returns from the sea surface
Presymptomatic Agent Exposure Detection
An algorithm that exploits data from noninvasive wearable medical sensors to detect if a person had been exposed to viruses or bacteria several days before overt symptoms, such as fever, appear.
CODEVELOPERS: STAFF FROM THE NATIONAL INSTITUTES OF HEALTH AND U.S. ARMY MEDICAL RESEARCH INSTITUTE OF INFECTIOUS DISEASES

Pulse-to-Pulse Phase Diversity Processing for Interference Suppression and Range Disambiguation
A low-cost technique that uses phase-diverse waveforms and specialized processing to help mitigate the interference that wind turbines can impose on radars that track aircraft and weather.

Wide-Area Infrared System for Persistent Surveillance
A portable system that detects and alerts operators to all moving objects in a monitored area during both day and night surveillance.
Airborne Collision Avoidance System for Unmanned Aircraft

A system that processes multisensor data to allow unmanned aircraft to detect and track nearby aircraft and to enable ground operators to direct safe separation between unmanned vehicles and other air traffic.

CODEVELOPERS: STAFF FROM THE FEDERAL AVIATION ADMINISTRATION, STANFORD UNIVERSITY, JOHNS HOPKINS APPLIED PHYSICS LABORATORY, AND MITRE

Enterophone™

A wireless, ingestible device that monitors heart and breathing rates by listening to the body’s sounds and that senses core temperature, all from within the gastrointestinal tract.

CODEVELOPERS: RESEARCHERS FROM MIT

Broadband Magnetometry and Temperature Sensing with a Light-Trapping Diamond Waveguide

An ultrasensitive magnetic-field detector and temperature sensor that is 1000 times more energy-efficient than previous diamond-based magnetometers.

CODEVELOPERS: FACULTY AND STUDENTS FROM MIT

Laserscope

A tool set that offers surgical navigation and precise laser targeting within the spinal cavity to enable treatment of back pain with an outpatient procedure instead of with open back surgery.

CODEVELOPERS: STAFF FROM MASSACHUSETTS GENERAL HOSPITAL AND DUKE UNIVERSITY
Offshore Precipitation Capability
A system that provides weather information for air traffic controllers by generating “radar-like” depictions of storms in offshore regions that are outside radar coverage
CODEVELOPERS: STAFF FROM THE FEDERAL AVIATION ADMINISTRATION

Small Airport Surveillance Sensor
A low-cost secondary surveillance system that provides airport tower controllers with situational awareness of aircraft on the airport surface and in nearby airspace

Platform for Architecture-Neutral Dynamic Analysis
An open-source, plug-in software analysis framework that enables computer engineers to observe code as a program executes so they can understand and mitigate vulnerabilities or faults in the code
CODEVELOPERS: STAFF FROM NEW YORK UNIVERSITY’S TANDON SCHOOL OF ENGINEERING, GEORGIA INSTITUTE OF TECHNOLOGY, AND NORTHEASTERN UNIVERSITY

Video Content Summarization Tool
A software application that creates summary views of long-duration surveillance videos so analysts can quickly identify activity of interest

Self-Defense Distributed Engagement Coordinator
An automated decision support tool that guides naval personnel on how to efficiently allocate resources in response to anti-ship missile threats
CODEVELOPERS: RESEARCHERS FROM MIT
Airborne Sense-and-Avoid Radar Panel

A novel stepped-notch antenna array that supports aircraft and weather detection and tracking modes in a single multifunction aperture.

Curled Microelectromechanical Switch

A curled-electrode switch that eliminates the sticking and contamination issues inherent in traditional electromechanical switches.

Haystack Ultrawideband Satellite Imaging Radar

A ground-based, dual X- and W-band sensor that can produce very high-resolution images of objects orbiting Earth.

CODEVELOPERS: STAFF FROM SIMPSON, GUMPERTZ, AND HEGER, AND COMMUNICATIONS AND POWER INDUSTRIES.
Localizing Ground-Penetrating Radar

A robust sensor that provides highly accurate, real-time vehicular position estimates based on prior mapping of subsurface features.

Lunar Laser Communication System

An optical system that achieves very high uplink and downlink data rates between an Earth terminal and a distant satellite.

Wide-Area Chemical Sensor

A highly precise, self-referencing spectrometer that measures the concentrations of specified target gases within the atmosphere.
Structured Knowledge Space

A software and information system that enables analysts to mine the vast store of intelligence reports available to government decision makers.

Ingest and parsing

Metadata enrichment
- “inter”
- “electricity”
- “vbid”

Discovery services
- Document facet service
- Lucene search engine
- Gazetteer service

Analyst tools
- Faceted search
- Geospatial search

Keywords
- “intel”
- “electricity”
- “vbied”

Named entities
- Jarbar Nahr
- Mohamed al-Marzug

Patterns
- “16 1830 APR 06”
- “3855MB441847”

Ingest and parsing

2013 WINNER

Photoacoustic Sensing of Explosives

A system that detects and discriminates trace amounts of explosives from significant standoff distances.

Lincoln Open Cryptographic Key Management Architecture

A highly portable software library that enables cryptographic protection for communication devices.

Unmanned aerial vehicle (UAV) video accessible only to authorized terminals

2012 WINNER

Route Availability Planning Tool

An automated decision support tool that predicts the availability of air traffic routes during thunderstorms.

CODEVELOPERS: STAFF FROM THE FEDERAL AVIATION ADMINISTRATION
**2012 WINNER**

**Wide Field-of-View Curved Focal Plane Array**
A curved, charge-coupled device that corrects for inherent aberrations of the mirrors and lenses in optical systems
CODEVELOPERS: STAFF FROM SUNSHINE AERO INDUSTRIES

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**2011 WINNER**

**Airborne Ladar Imaging Research Testbed**
An airborne laser radar that rapidly collects high-resolution three-dimensional imagery of wide-area terrains
CODEVELOPERS: STAFF FROM SUNSHINE AERO INDUSTRIES

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**2012 WINNER**

**Wavelength Beam-Combining Fiber-Coupled Diode Laser**
A high-intensity diode laser that combines unprecedented brightness, efficiency, and reliability
CODEVELOPERS: STAFF FROM TERADIODE
**EDITOR'S CHOICE AWARD WINNER**

This technology was also the winner of an R&D Editor's Choice Award, which is given to the three R&D 100 Award winners that the magazine's editors believe are the most innovative and impactful.

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**2011 WINNER**

**Multifunction Phased Array Radar Panel**

A panel of phased arrays that exploits dual polarization and digital beamforming to provide efficient radar detection and tracking of aircraft and weather targets.

**CODEVELOPERS: STAFF FROM M/A-COM TECHNOLOGY SOLUTIONS**

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**2011 WINNER**

**Parallel Vector Tile Optimizing Library**

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

---

**2011 WINNER**

**Pathogen Analyzer for Threatening Environmental Releases**

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

---

**Detection Process**

1. Bioagent–containing aerosol is collected; disc is spun after collection to release B cells.
2. Pathogens crosslink antibodies.
3. Biochemical signal amplification releases Ca^{2+}.
4. Ca^{2+} prompts aequorin to emit photons.
5. Photons are detected by sensor.
**Digital-Pixel Focal Plane Array**

A complementary metal-oxide semiconductor readout integrated circuit for infrared imaging that is capable of an extreme dynamic range.

**Miniaturized Radio-Frequency Four-Channel Receiver**

The smallest, least power-demanding receiver that can detect frequencies over a six-octave range.

**Geiger-Mode Avalanche Photodiode Detector Focal Plane Array**

A two-dimensional array of ultrasensitive solid-state photodetectors, each of which can measure the arrival time of single photons.
A system integrating data from airport surveillance sources to control in-pavement lights that directly alert pilots to potential runway incursions.

A component in an optical detection system that enables broadband single-photon detection with high efficiency and low noise at rates exceeding one billion photons per second.

In addition, Lincoln Laboratory received two earlier R&D 100 Awards:

1998 jointly with Cyra Technologies and the Los Alamos National Laboratory for a three-dimensional laser mapping and imaging system

1995 for a technology that determines a plane’s position by using GPS

Earlier R&D 100 Award Winners

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