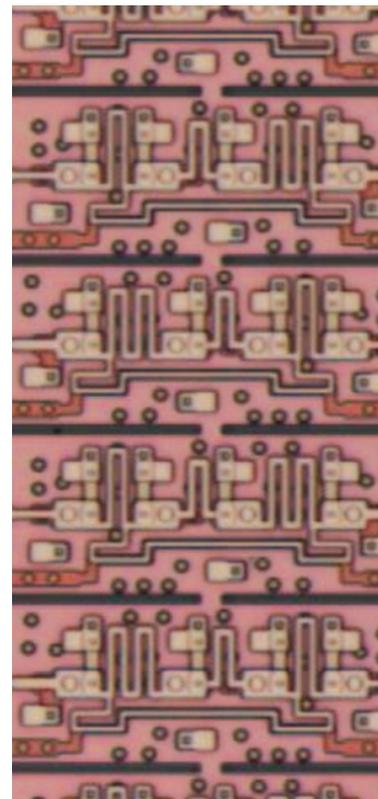
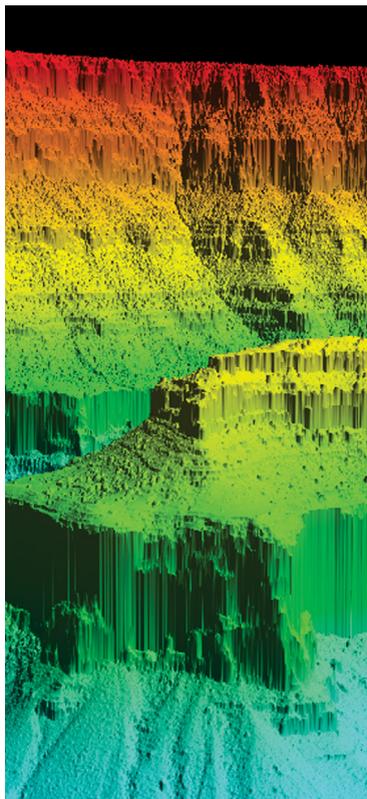


## R&D 100 Awards

75

## MIT LINCOLN LABORATORY

technologies recognized as among the best innovations of each year, 2010–2021





## *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
- Advanced imaging
- Cybersecurity
- Data analytics
- Microelectronics
- Bioengineering
- Air and missile defense
- Space systems

[www.ll.mit.edu](http://www.ll.mit.edu)

# Letter from the Director

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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 75 of these awards—including two R&D Editor's Choice Awards—over the past 12 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 also 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. The 2021 R&D 100 Award recipients were recognized virtually as a precaution motivated by the COVID-19 pandemic.

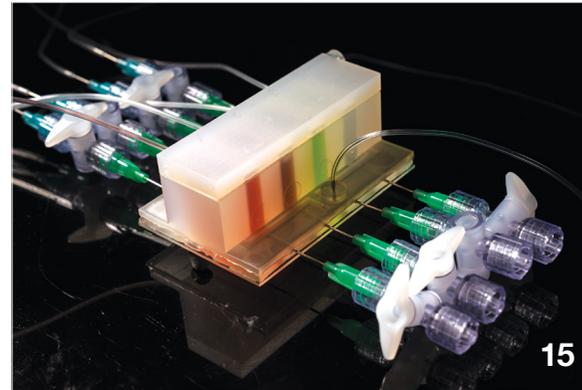
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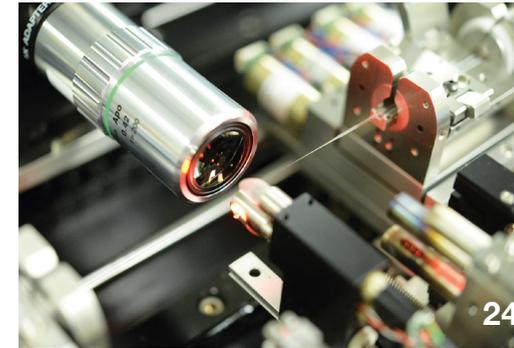
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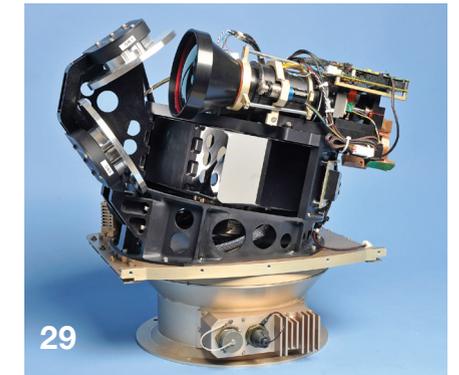
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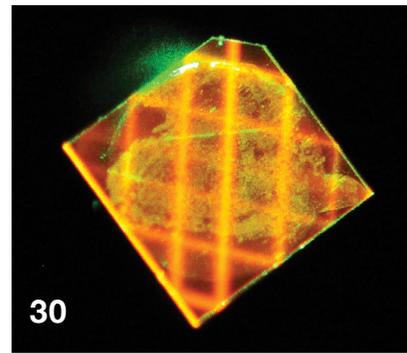
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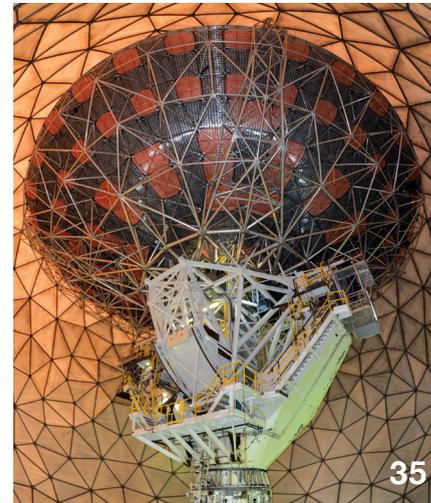
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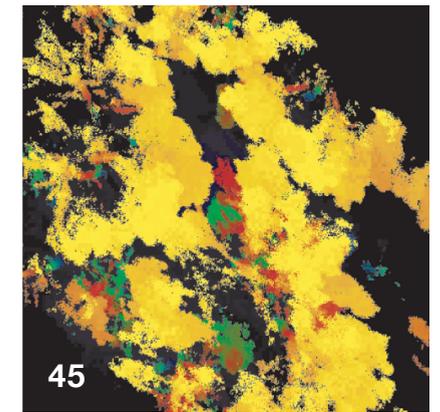
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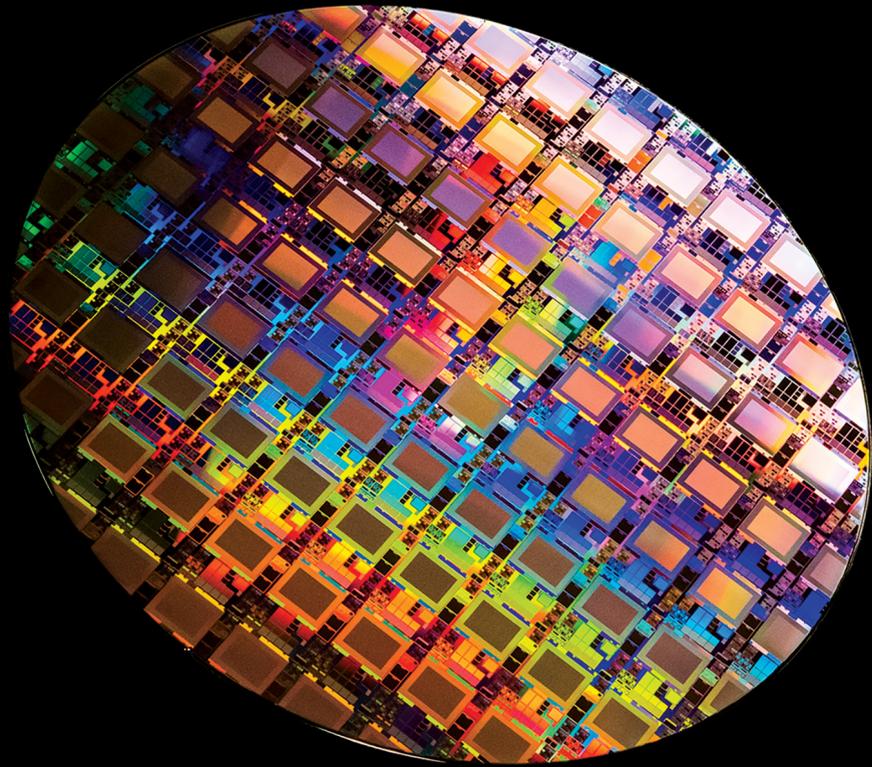
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2021  
WINNER

## Field-Programmable Imaging Array

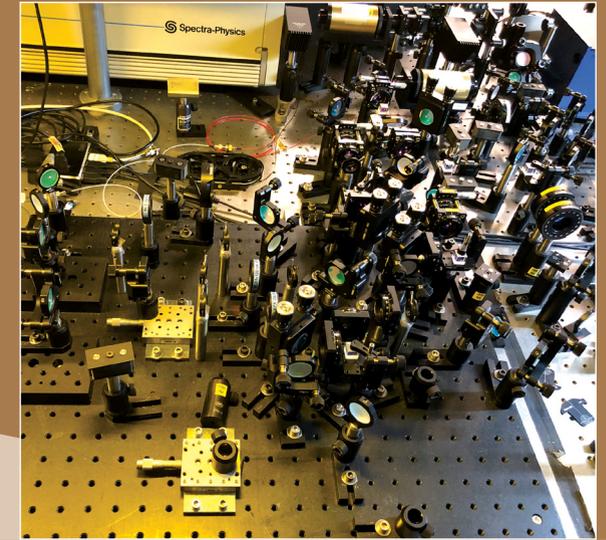
A universal digital back end for camera systems that, when hybridized to an image detector array, results in a flexible and powerful digital processing system-in-package



## Free-Space Quantum Network Link Architecture

A system that enables the generation, distribution, and remote interaction of entangled photons across free-space links

2021  
WINNER



## Global Synthetic Weather Radar

2021  
WINNER

A technology that provides radar-like weather imagery and radar-forward forecasts in global regions where actual weather radar are not deployed or available



2021  
WINNER



## Guided Ultrasound Intervention Device

A handheld tool, utilizing real-time artificial intelligence software, that enables a medic to rapidly and accurately catheterize a central vein or artery in a prehospital environment



## Microhydraulic Motors

A scalable, electrowetting-based actuation platform with a torque density two orders of magnitude higher than that of electric motors

2021  
WINNER

2021  
WINNER

## Motion Under Rubble Measured Using Radar

A lightweight, portable life-detection radar that rapidly senses, ranges, and characterizes survivors trapped beneath rubble



## Monolithic Fiber Array Launcher

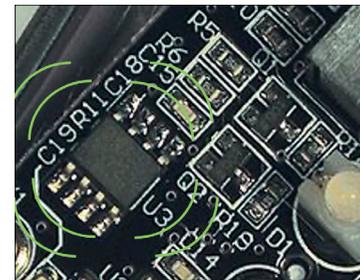
An all-glass, monolithic fiber array launcher that is smaller and more robust than standard arrays

2021  
WINNER

2021  
WINNER

## Spectrally Efficient Digital Logic

A set of digital logic families that operate with intrinsically low electromagnetic interference emissions

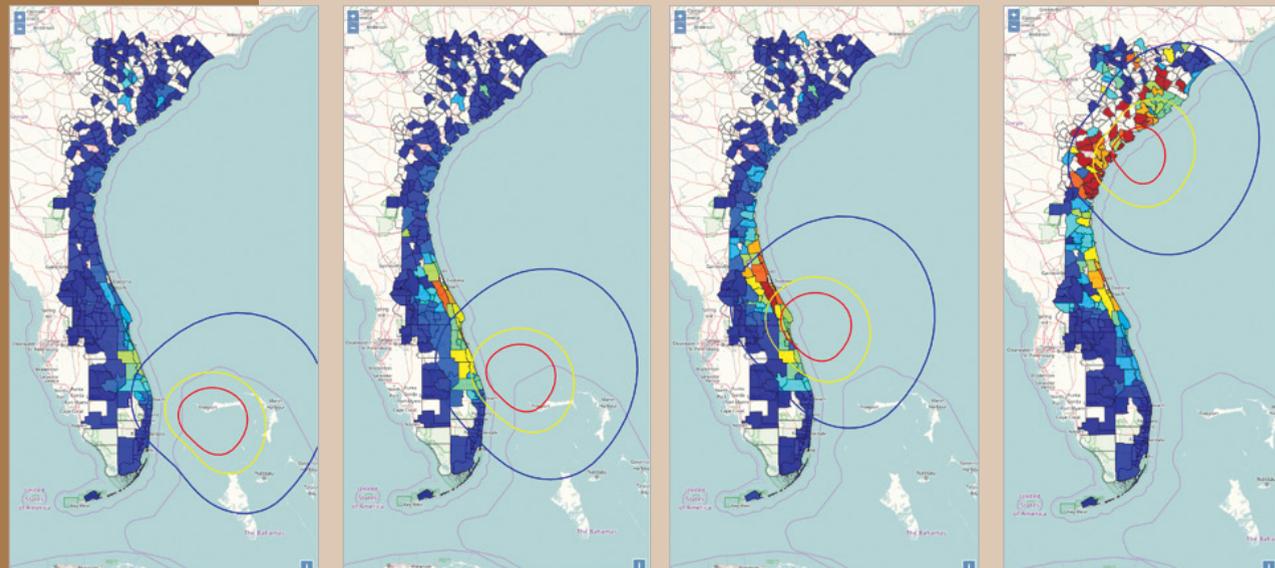


## Traffic Flow Impact Tool

A tool for air traffic control managers that predicts and displays impacts to airspace capacities and traffic flow rates during convective weather

2021  
WINNER





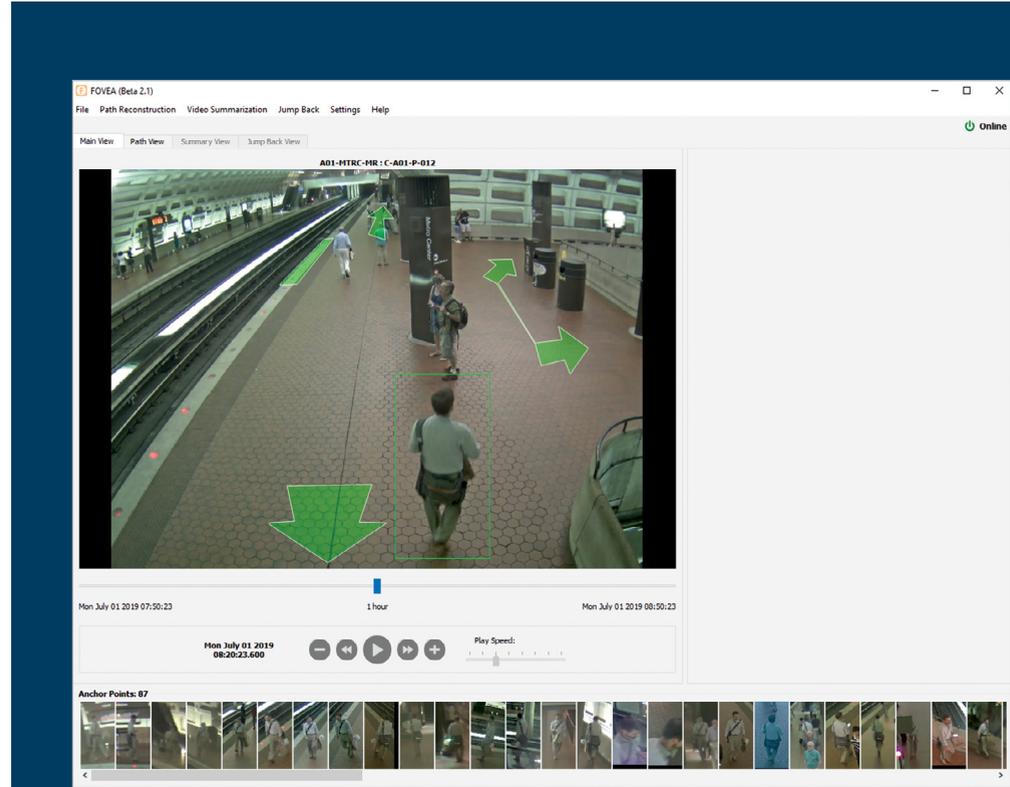
Town-wide response rates relative to baseline

- 0-10%
- 10-20%
- 20-30%
- 30-40%
- 40-50%
- 50-60%
- 60-70%
- 70-80%
- 80-90%
- 90-100%
- 100%+
- No data

2020 WINNER

### 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



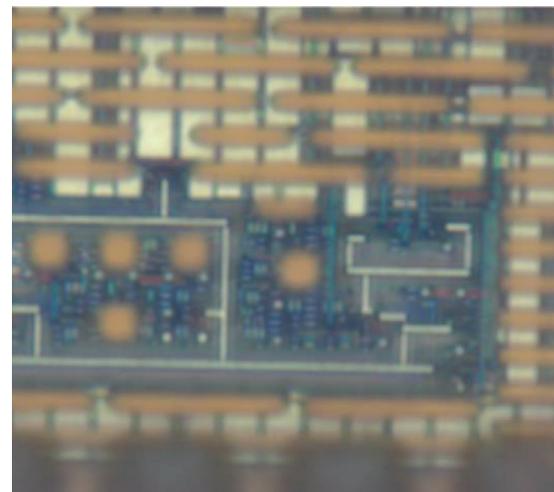
2020 WINNER

### 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

### 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



2020 WINNER

### 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

2020 WINNER

Keylime Advanced Tenant Management System

**Instances**

	UUID	address	status
+	b85055e9...	N/A	0 (Registered)
<b>Details:</b> id: b85055e9-5e27-4f3b-be80-4e7a27822df2 operational_state: 0 (Registered)			
+	D432FBB3...	127.0.0.1:9002	3 (Get Quote)
<b>Details:</b> ip: 127.0.0.1 id: D432FBB3-D2F1-4A97-9EF7-75B081C00000 operational_state: 3 (Get Quote) ima_whitelist_item: 0 v: 7bLk++GjVT7AMBRxFuPfyJAgow+6ZssLHg/vs+Yx9cE= tpm_policy: {}			

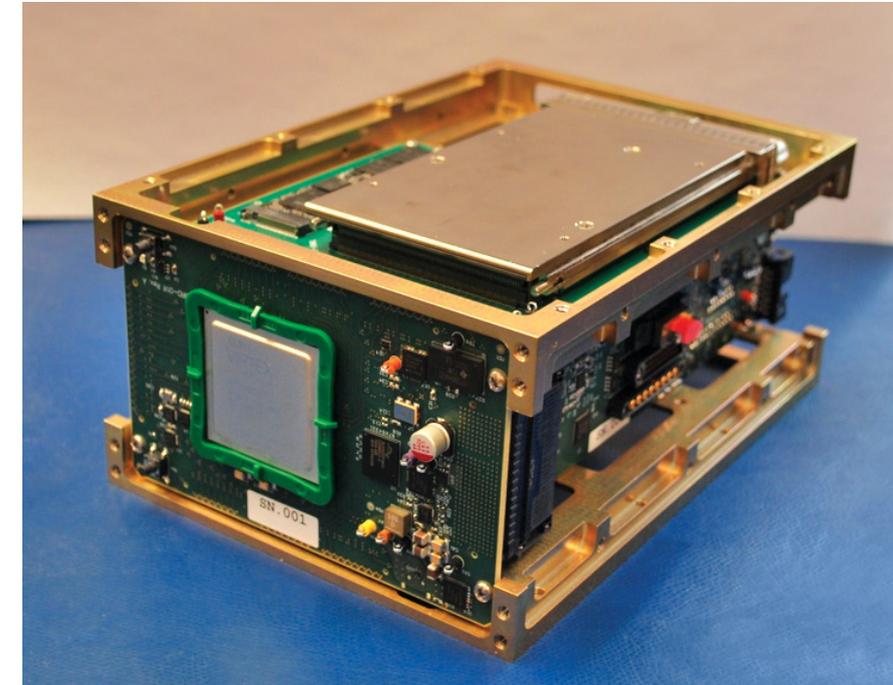
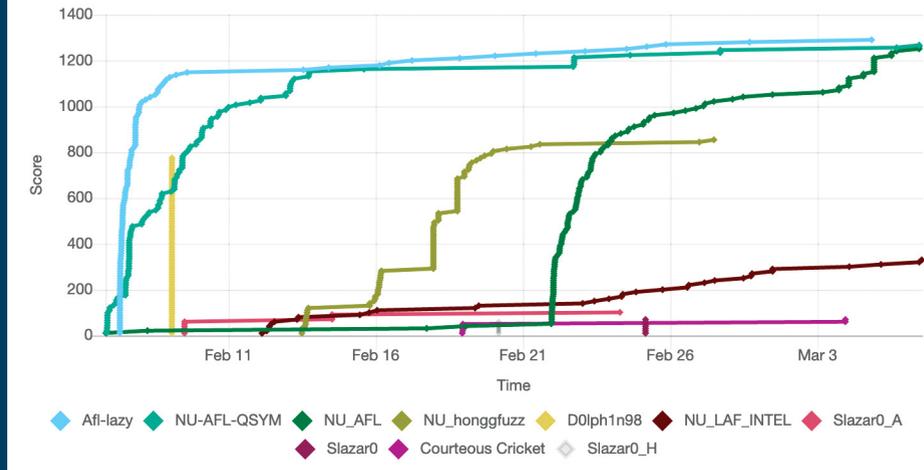
## Large-scale Vulnerability Addition

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

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

2020  
WINNER

Score Graph – All challenges



## 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

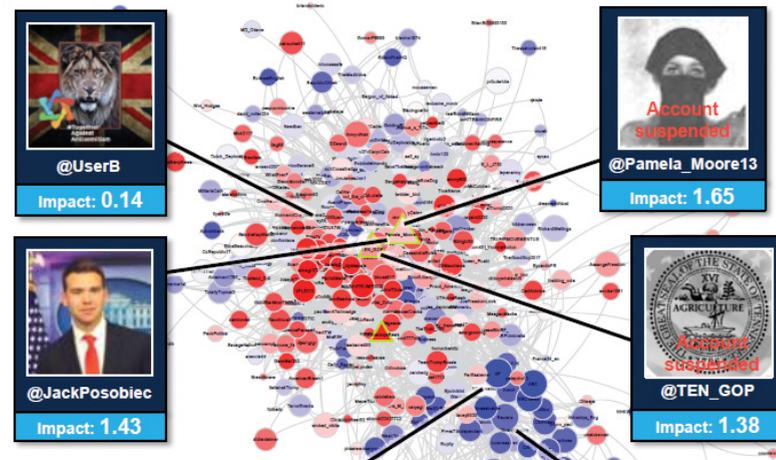
2020  
WINNER

2020  
WINNER

## 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

CODEDEVELOPERS: RESEARCHERS FROM HARVARD UNIVERSITY



## Timely Randomization Applied to Commodity Executables at Runtime

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

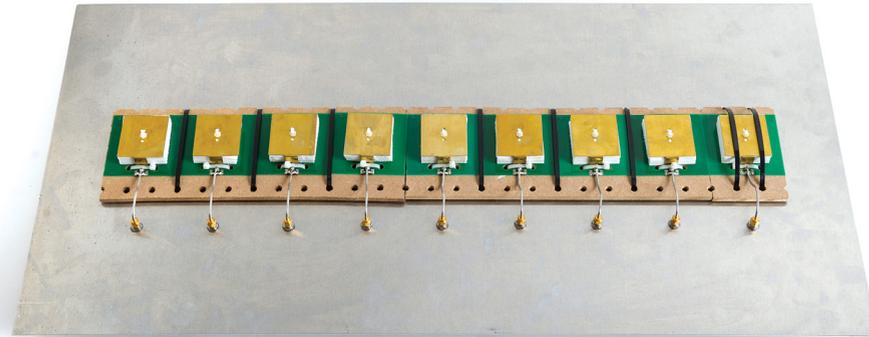


2020  
WINNER

2019  
WINNER

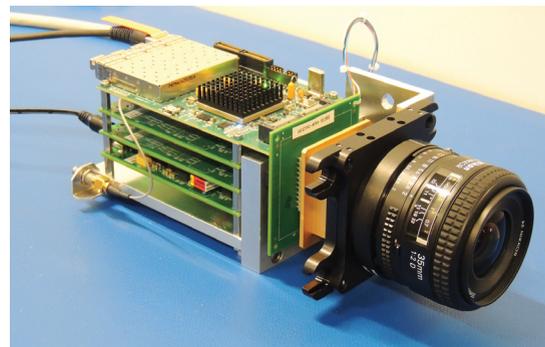
## Aperture-Level Simultaneous Transmit and Receive Phased Array

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

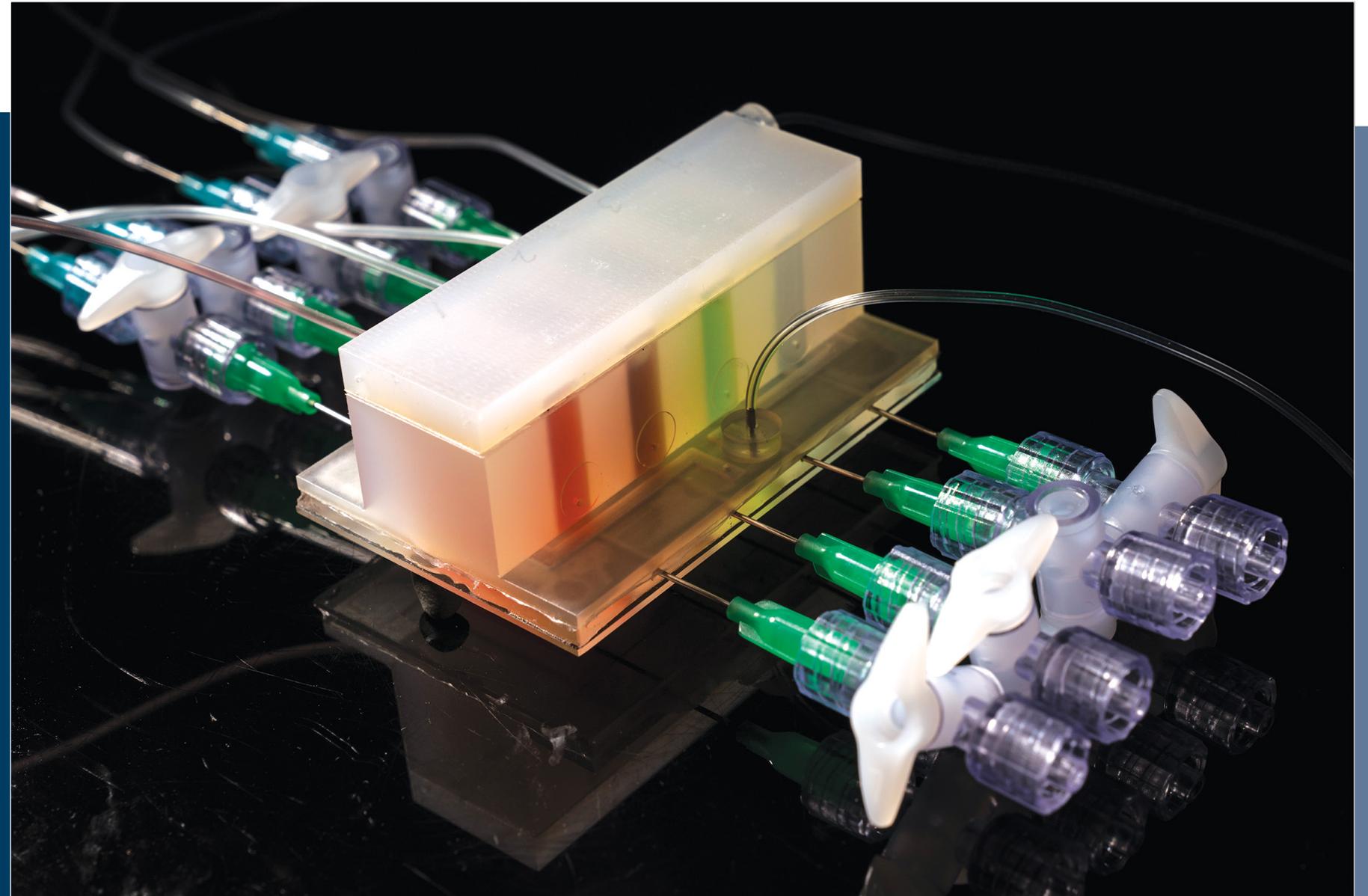


## Dual-Mode Imaging Receiver

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



2019  
WINNER



## ArtGut

The first in vitro platform that enables researchers to perform high-resolution, physiologically relevant gut microbiome studies

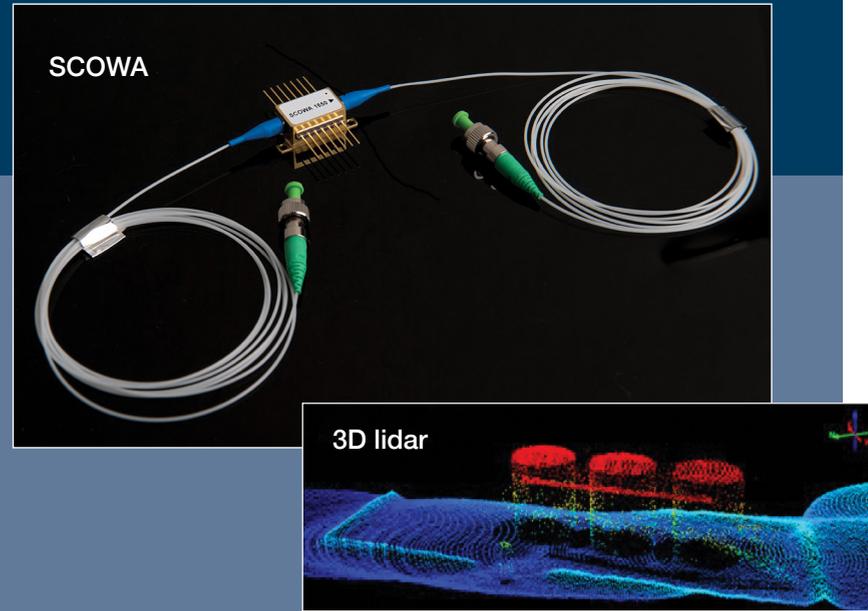
2019  
WINNER

2019  
WINNER

## 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

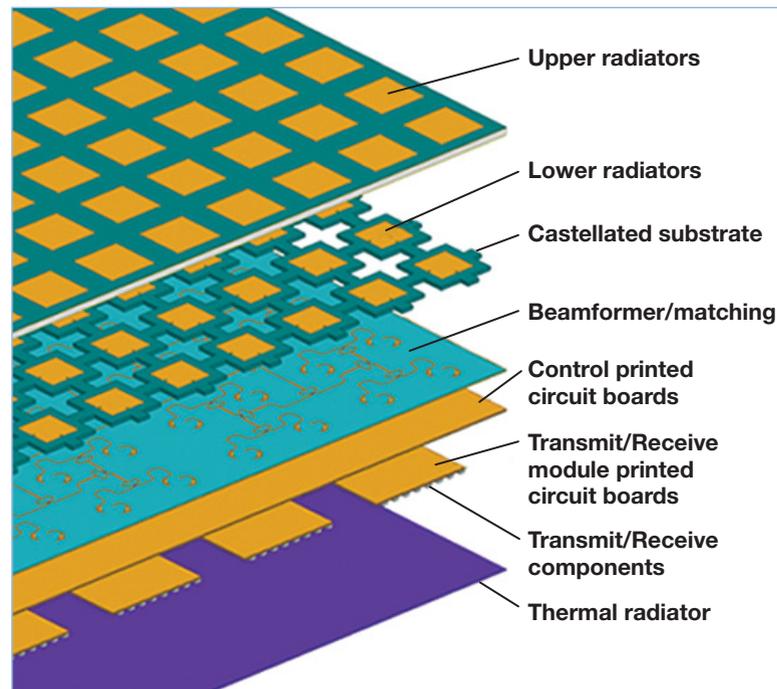
CODEVELOPERS: STAFF FROM BRIDGER PHOTONICS



2019  
WINNER

## Lightweight Deployable Array Panels for Space

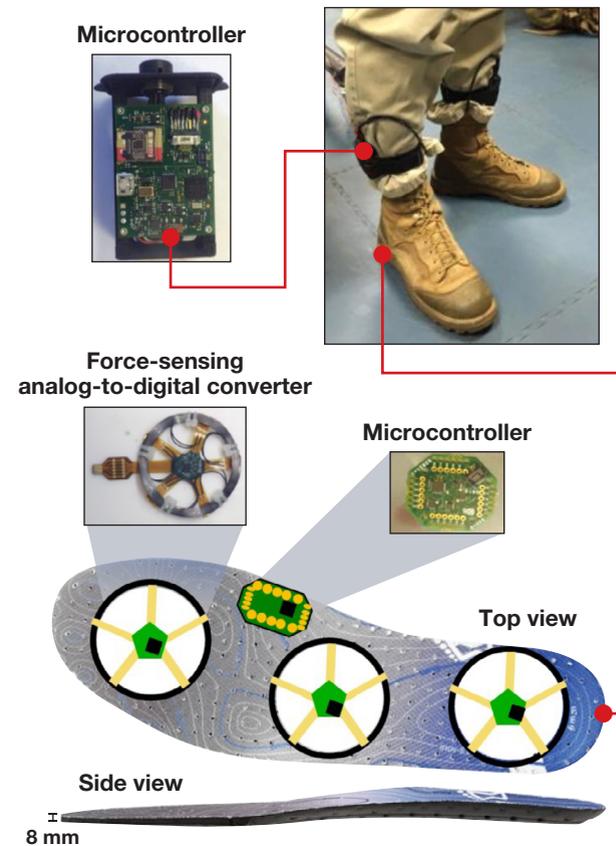
Panels for space-based communications and remote-sensing systems that have minimized weight and size to lower launch costs by reducing fuel needs and increasing capacity to accommodate more systems per launch



2019  
WINNER

## 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

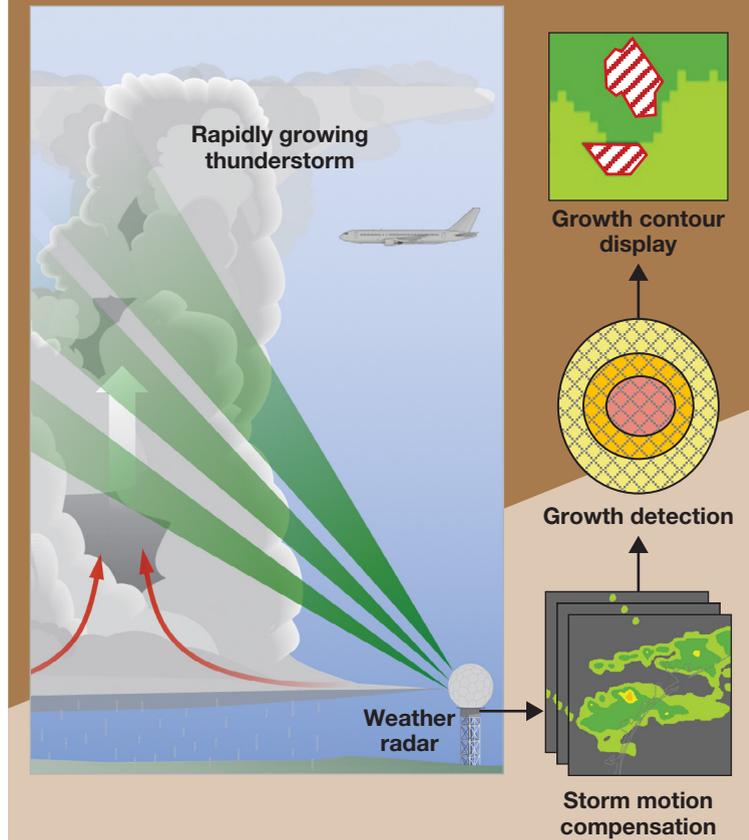


2019  
WINNER

## 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



2019  
WINNER

## Tactical Microgrid Standard Open Architecture



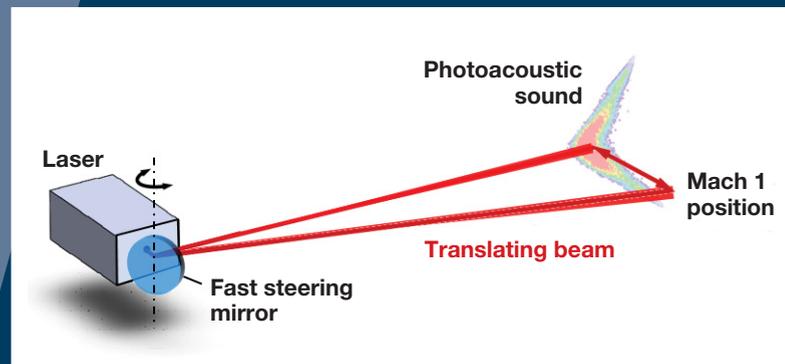
An architecture that was developed by a Department of Defense–led consortium of government, industry, and academic partners to provide an interoperability standard for highly modular, resilient, scalable, and mission-specific microgrid solutions

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

2019  
WINNER

## 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

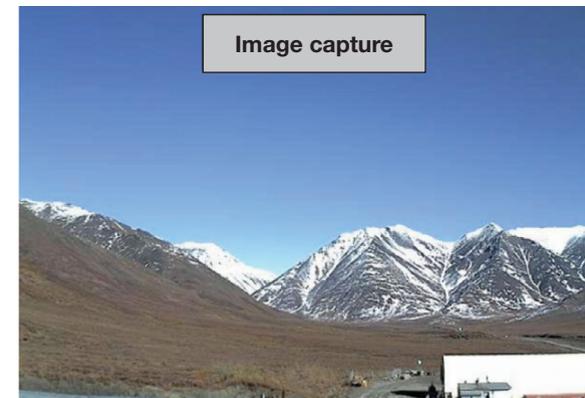


2019  
WINNER

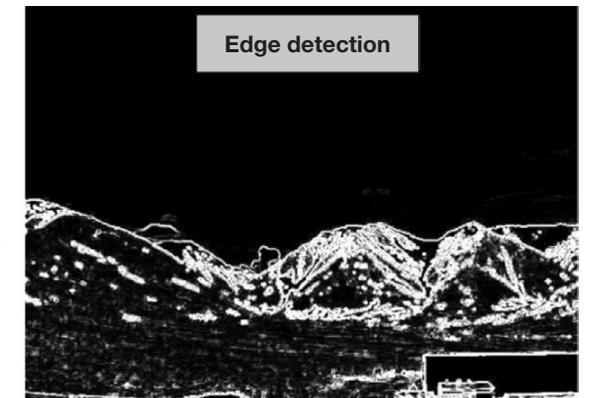
## Visibility Estimation through Image Analytics

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



10+ miles



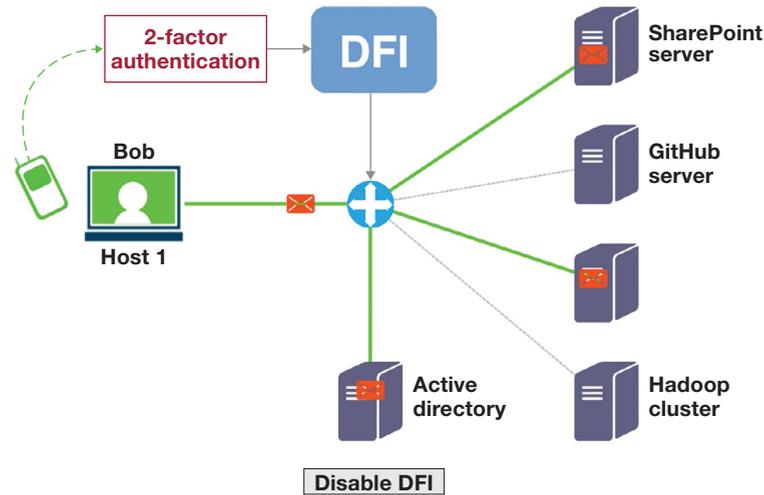
Quarter mile



2018  
WINNER

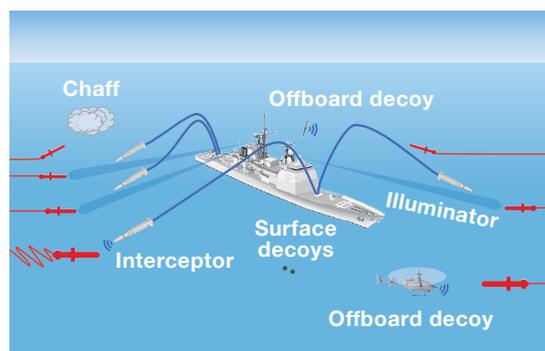
## Dynamic Flow Isolation

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

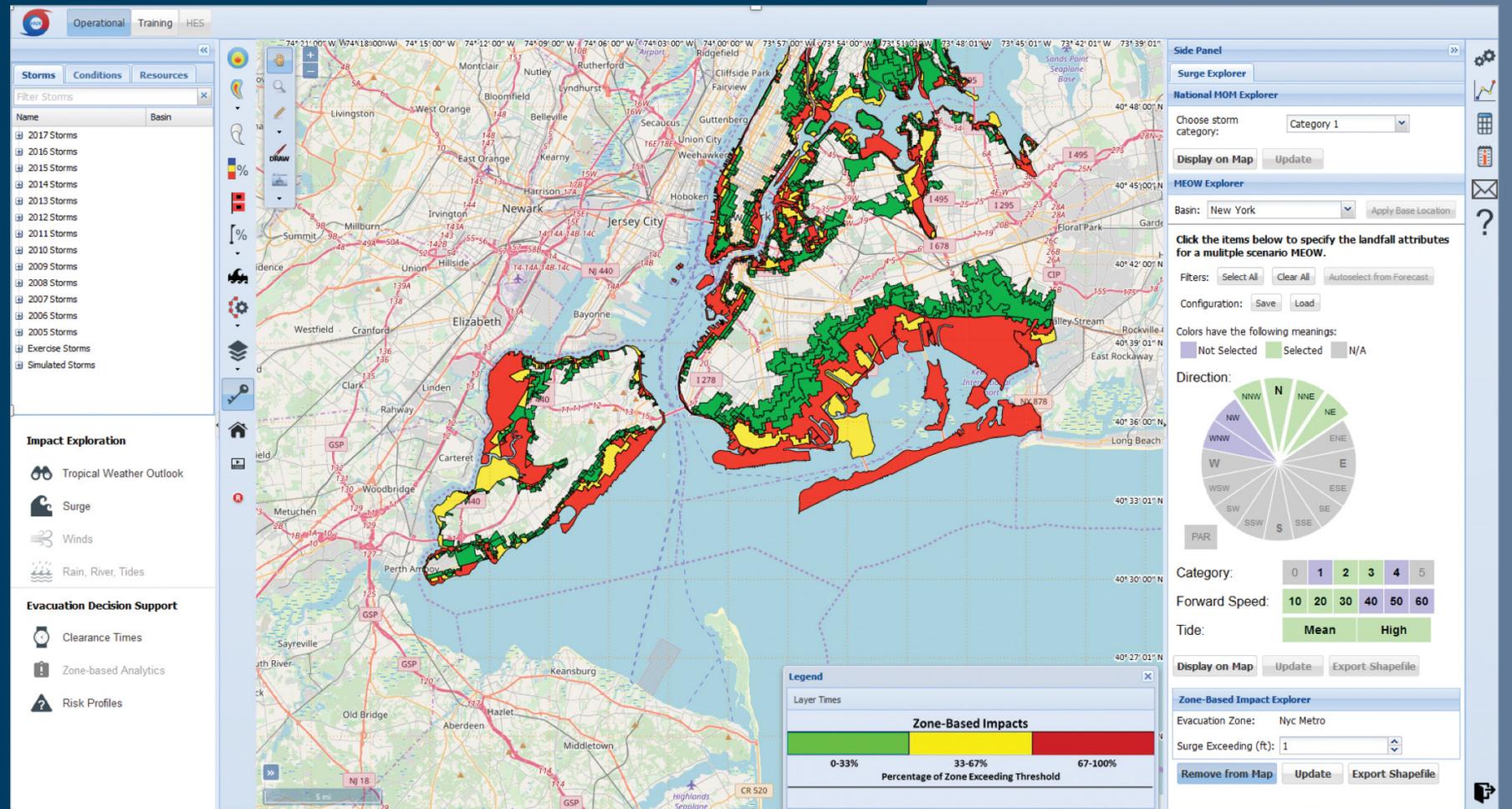


2018  
WINNER

2018  
WINNER

## Web-Based HURREVAC

An open-source decision support platform that enables emergency managers to plan, train for, and make accurate hurricane evacuation decisions





2018  
WINNER

### Immersive Imaging System

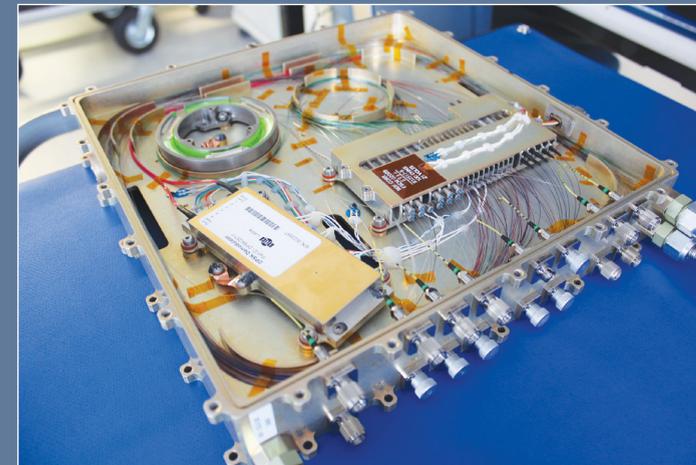
A wide-area video surveillance system that provides very high-resolution images and 360-degree coverage from a single vantage point



2018  
WINNER

### Intelligent Power Distribution

An electrical box that improves the efficiency and resiliency of a microgrid operating in austere conditions by coordinating the microgrid's energy resources and loads



### Multirate Differential Phase Shift Keying Optical Communications

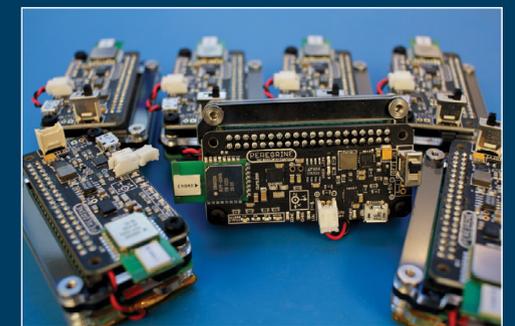
A format that enables efficient free-space laser communications over a wide range of data rates by using a single easy-to-implement transmitter and receiver design

2018  
WINNER

### 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

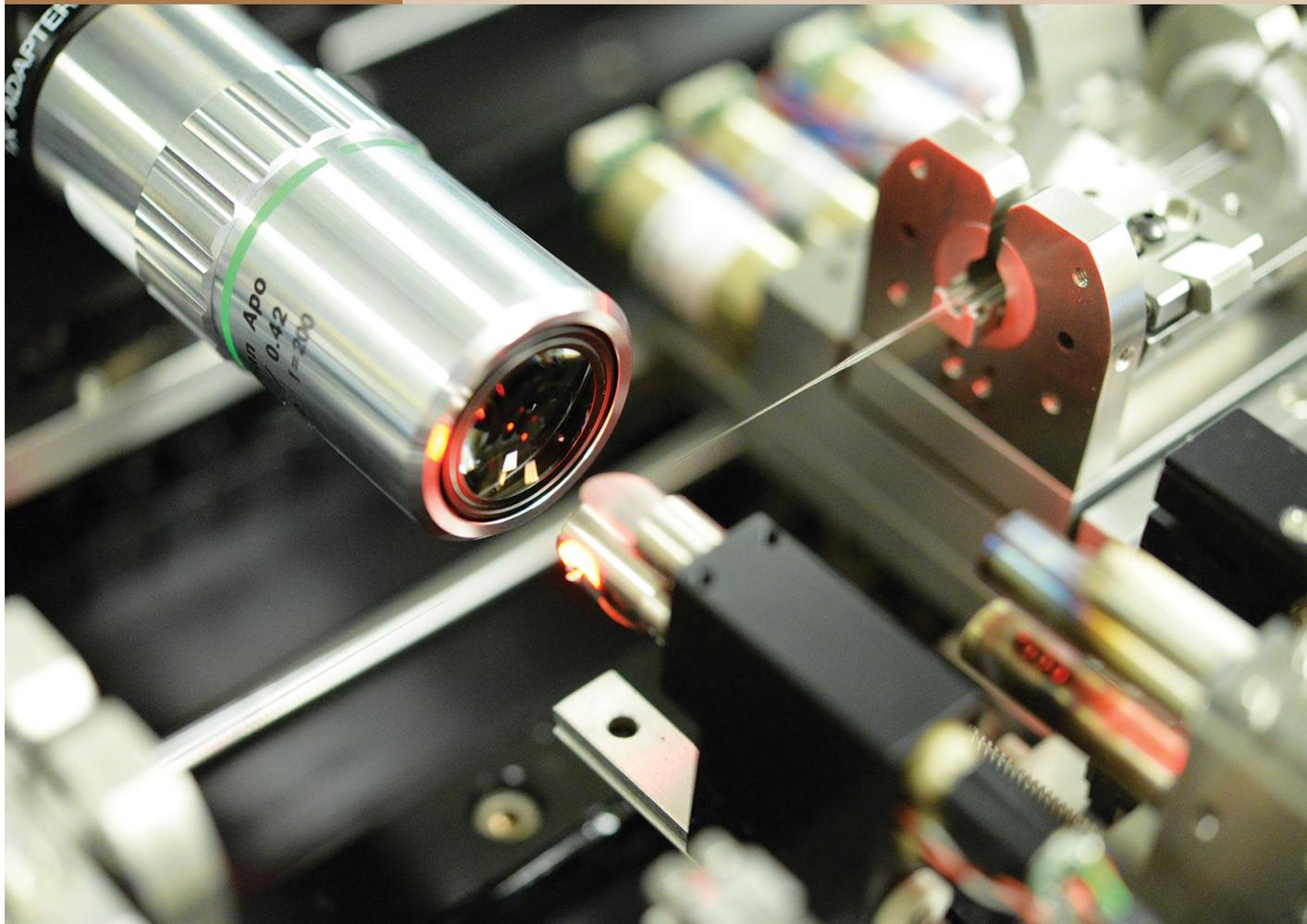


2018  
WINNER

2018  
WINNER

## 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

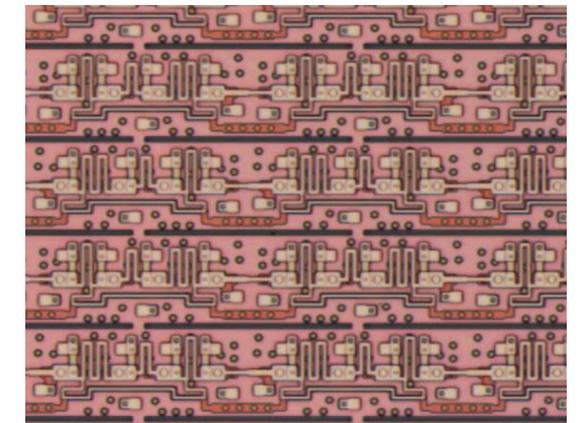
Algorithms that drastically reduce the compute time required to compare a large number of unknown DNA profiles against a large dataset of millions of reference DNA profiles

2018  
WINNER

2018  
WINNER

## 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

### CO<sub>2</sub>/O<sub>2</sub> 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

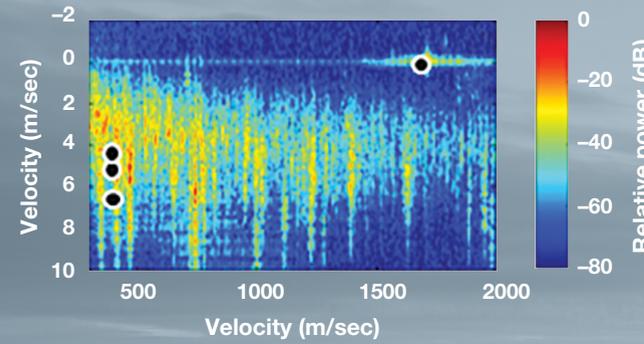


2017  
WINNER

### 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

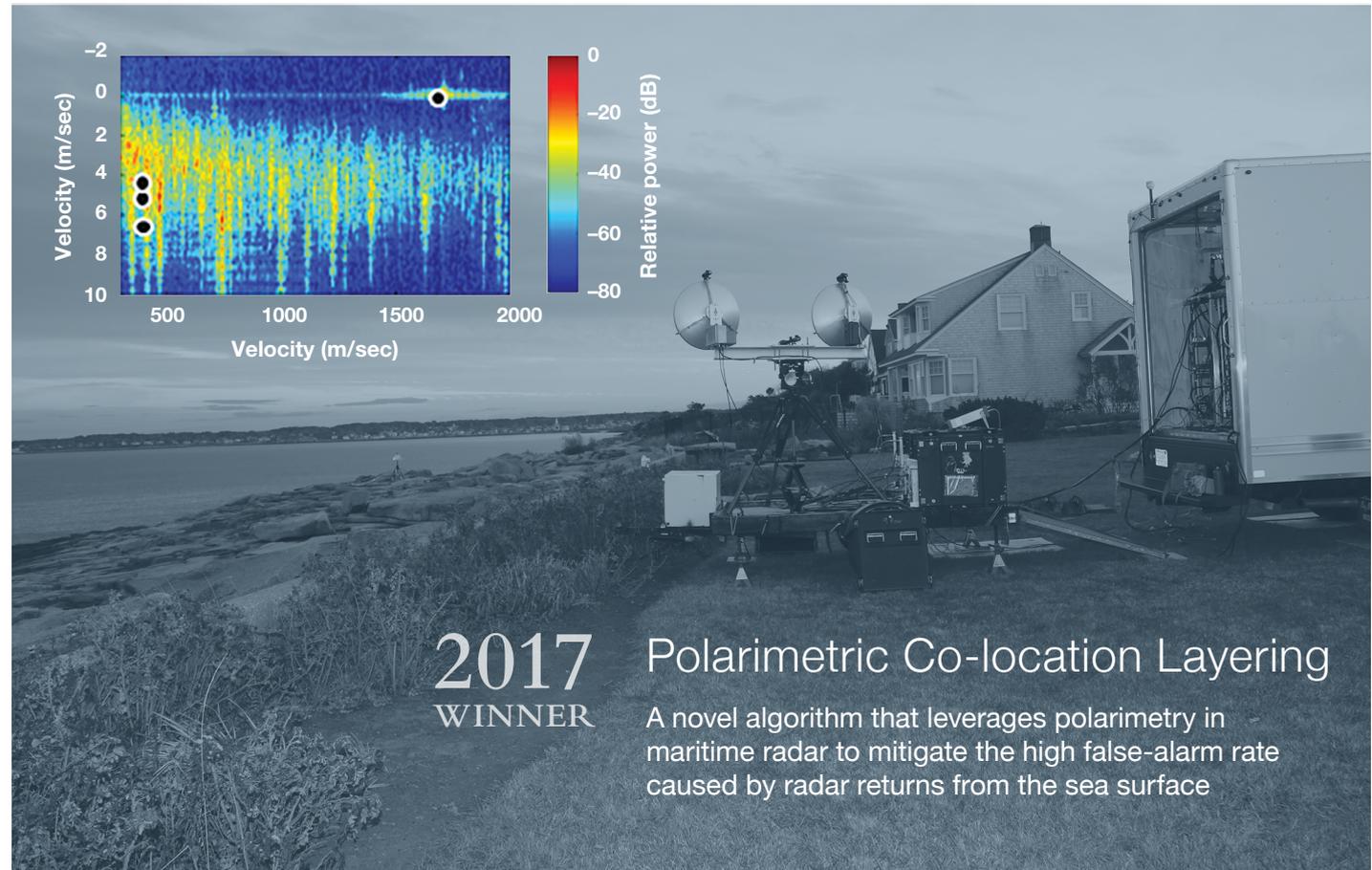
CODEVELOPERS: STAFF FROM THE U.S. ARMY, SRC INC., AND KUTTA TECHNOLOGIES



2017  
WINNER

### 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

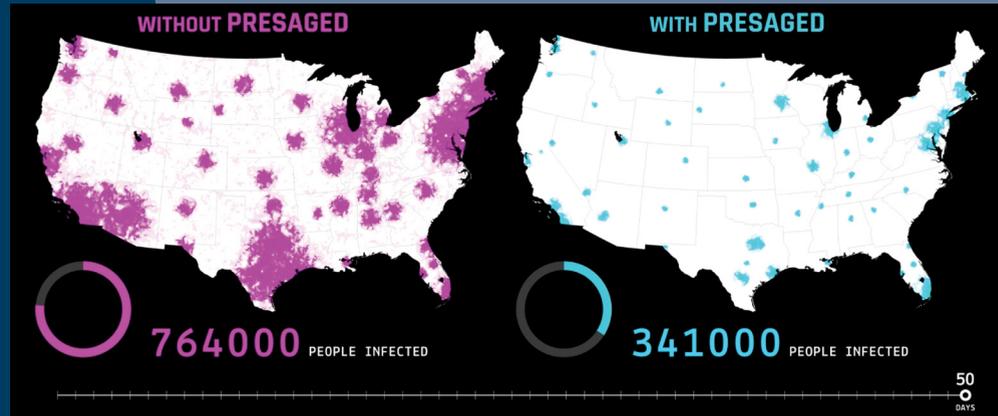
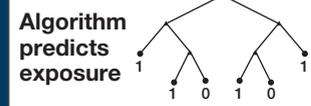
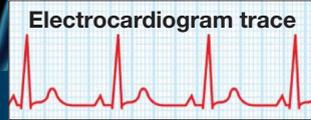
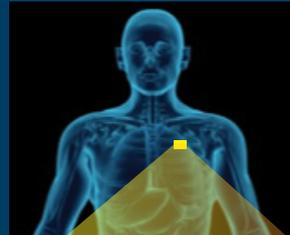


2017  
WINNER

## Presymptomatic Agent Exposure Detection

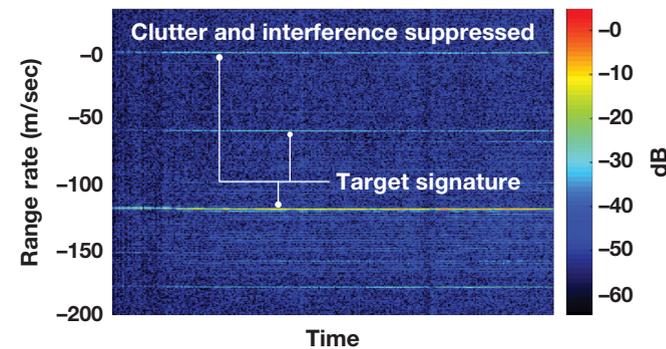
An algorithm that exploits data from noninvasive wearable medical sensors to detect if a person had been exposed to viruses or bacteria several days before overt symptoms, such as fever, appear

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

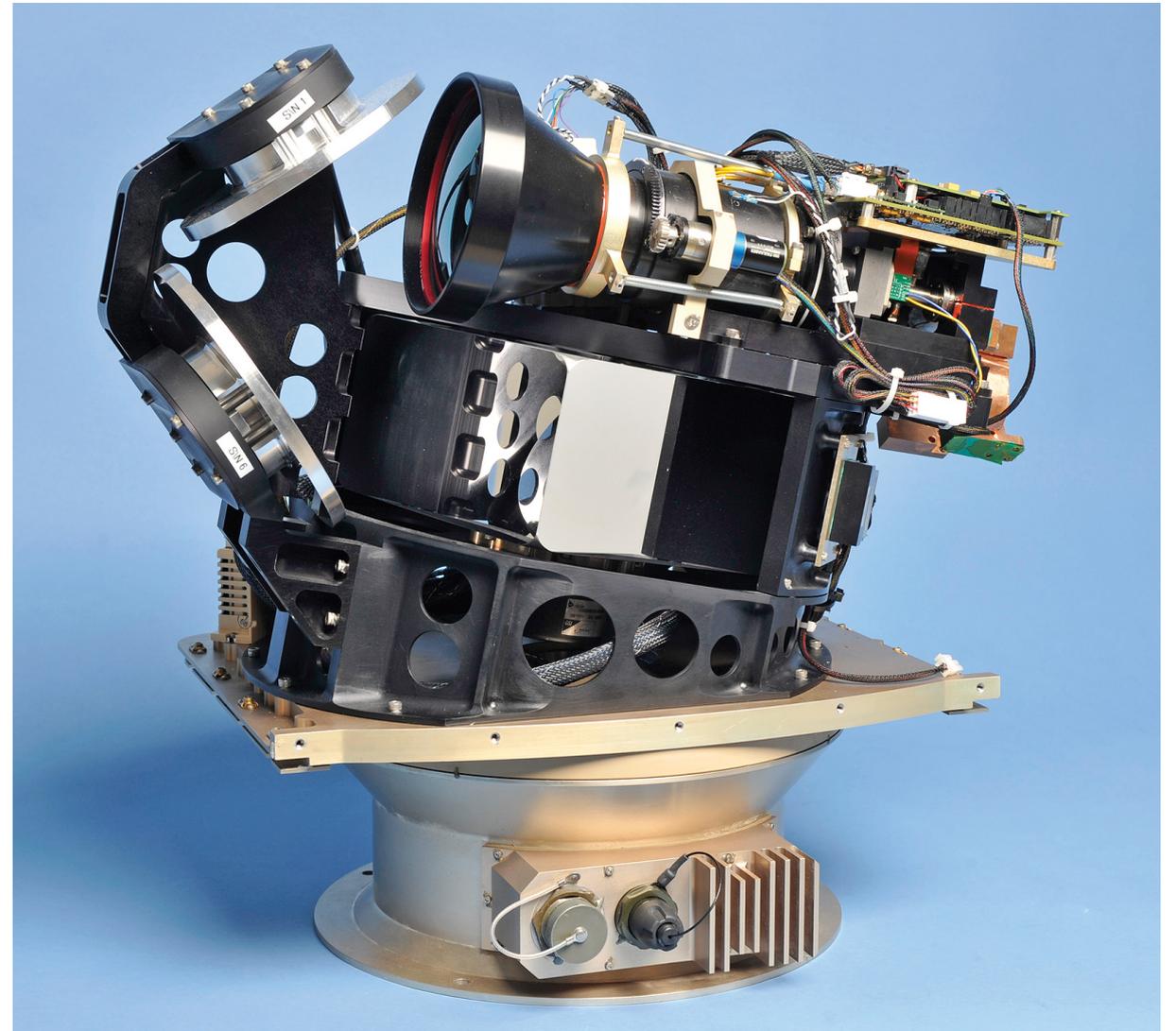


2017  
WINNER

2017  
WINNER

## 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

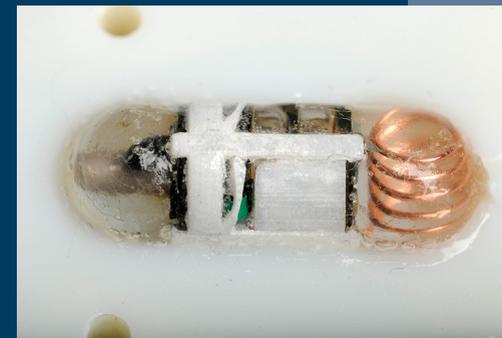


2016  
WINNER

## 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



2016  
WINNER

## 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

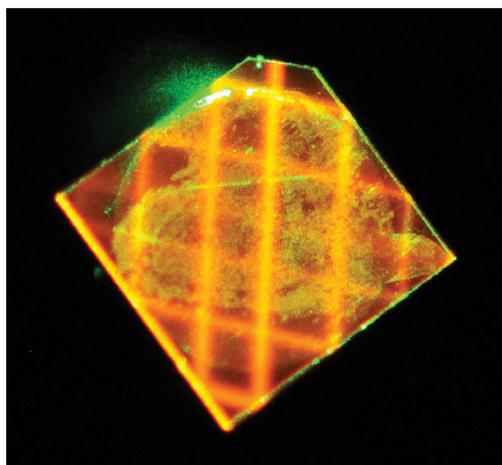
**CODEVELOPERS:** RESEARCHERS FROM MIT

2016  
WINNER

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

An ultrasensitive magnetic-field detector and temperature sensor that is 1,000 times more energy-efficient than previous diamond-based magnetometers

**CODEVELOPERS:** RESEARCHERS FROM MIT

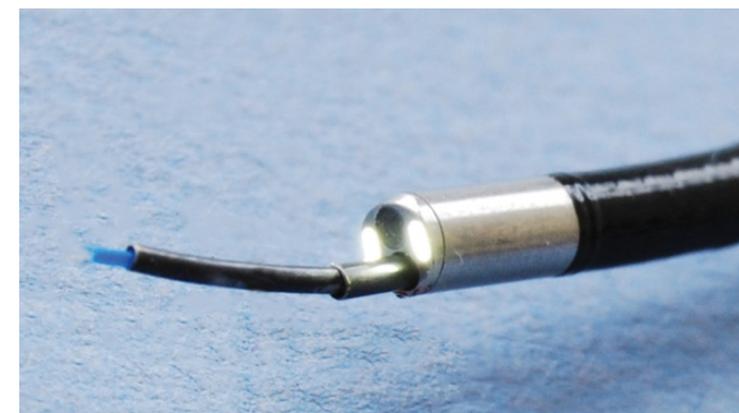


2016  
WINNER

## 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

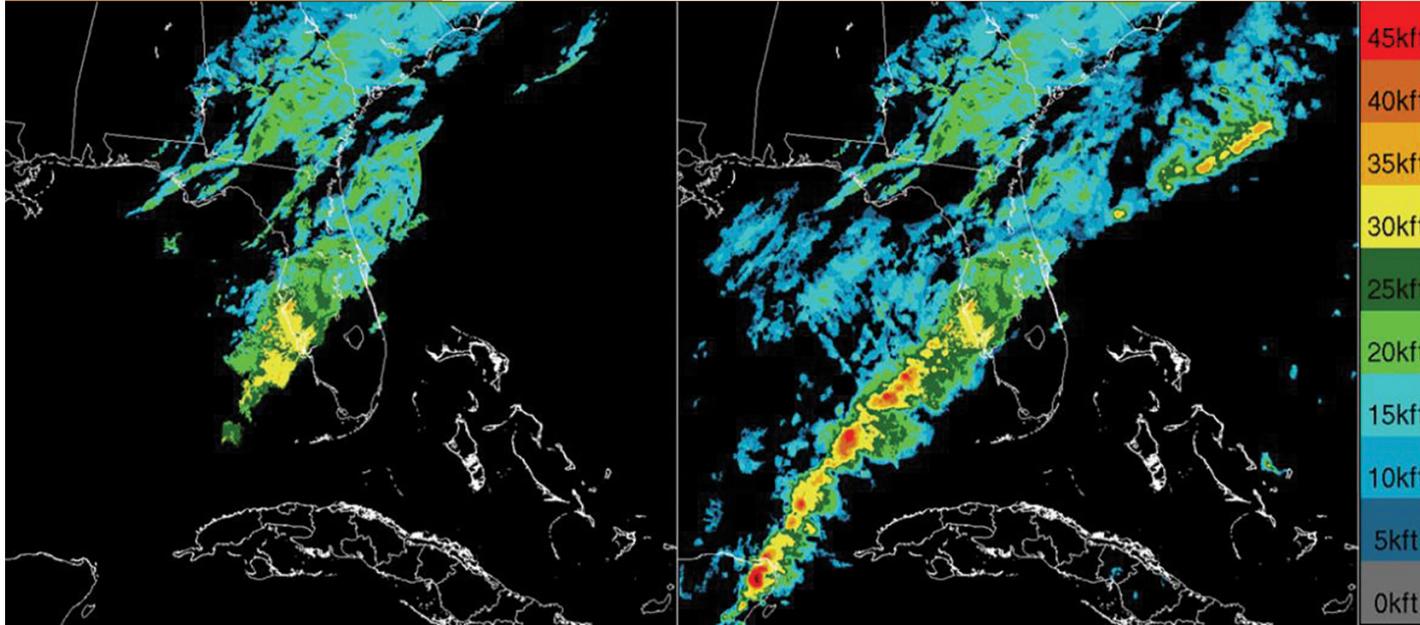


2016  
WINNER

## 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



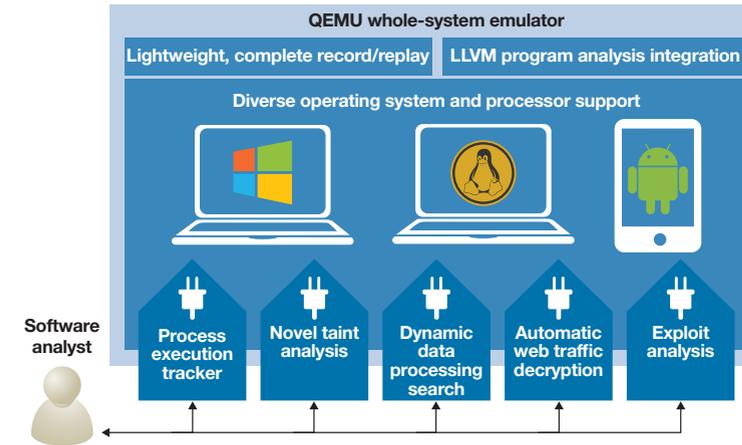
2016  
WINNER

## 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: RESEARCHERS FROM NEW YORK UNIVERSITY'S TANDON SCHOOL OF ENGINEERING, GEORGIA INSTITUTE OF TECHNOLOGY, AND NORTHEASTERN UNIVERSITY

2015  
WINNER

2015  
WINNER

## Video Content Summarization Tool

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

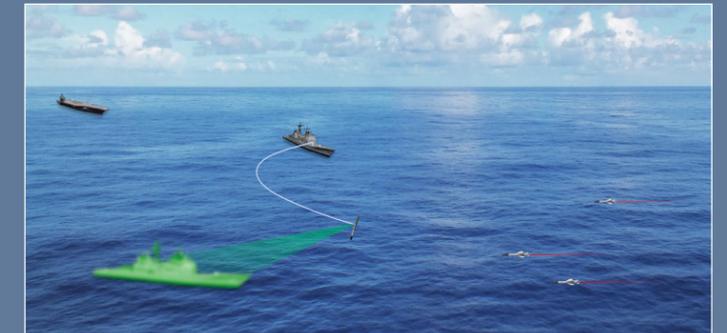


## Self-Defense Distributed Engagement Coordinator

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

2015  
WINNER





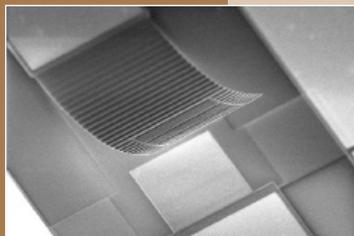
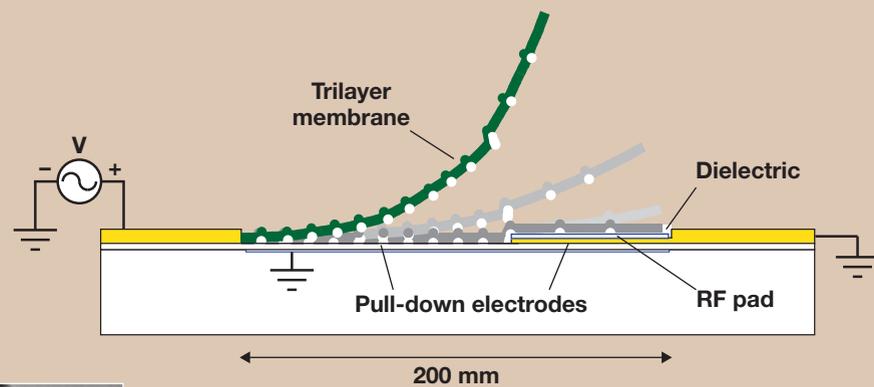
2014  
WINNER

### 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

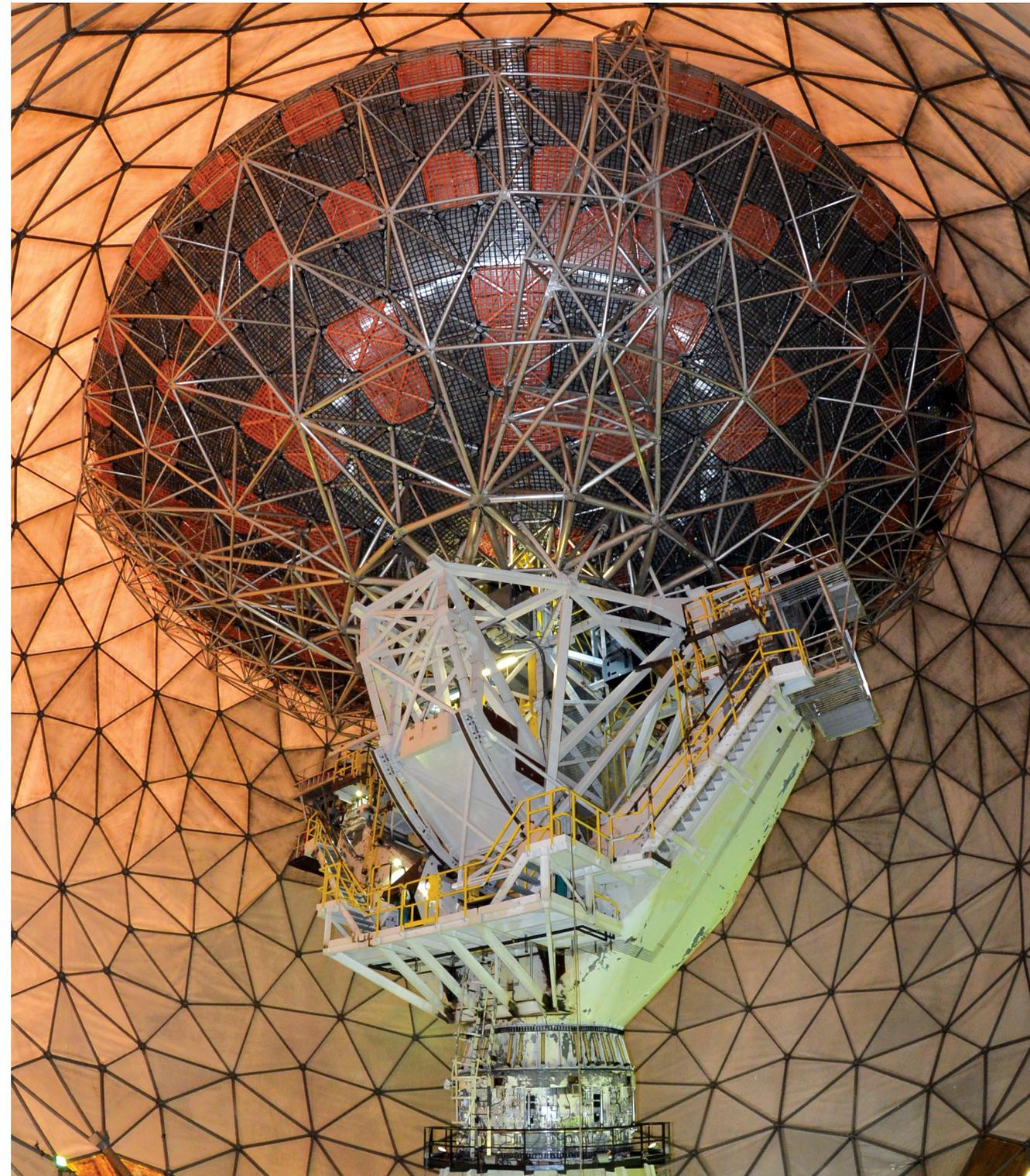
2014  
WINNER

### Curled Microelectromechanical Switch



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

CODEVELOPERS: STAFF FROM INNOVATIVE MICRO TECHNOLOGY



2014  
WINNER

### 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

EDITOR'S CHOICE AWARD WINNER

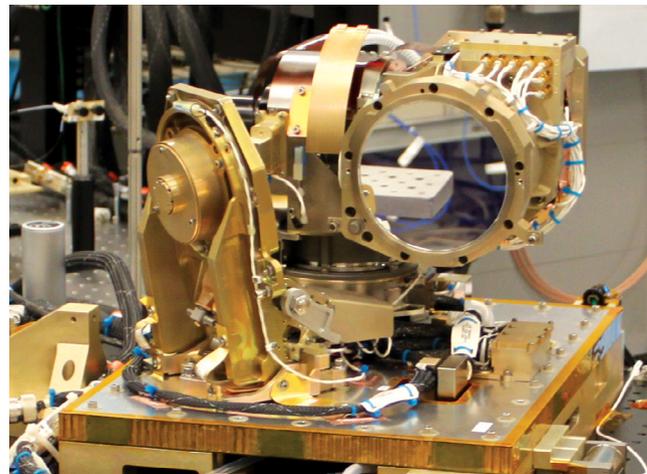
This technology was also the winner of an R&D Editor's Choice Award, which is given to the three R&D 100 Award winners that the magazine's editors believe are the most innovative and impactful

# 2014 Lunar Laser Communication System

WINNER

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

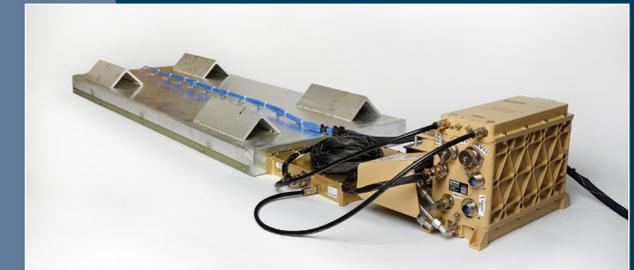
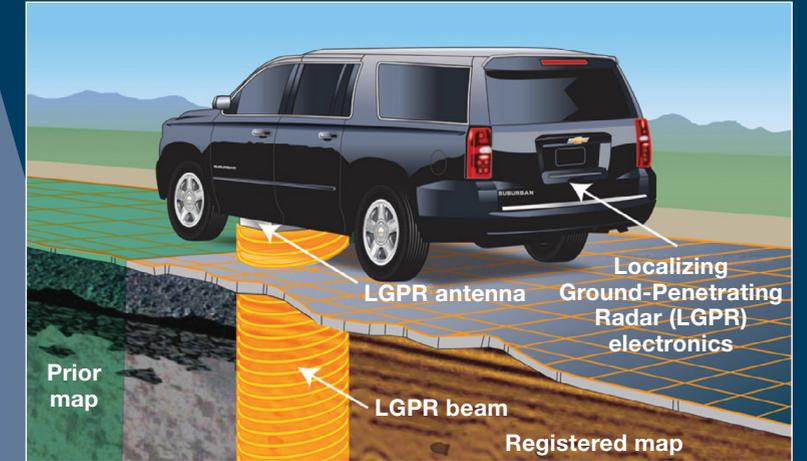
CODEVELOPERS: STAFF FROM NASA'S GODDARD SPACE FLIGHT CENTER AND NASA'S SPACE COMMUNICATIONS AND NAVIGATION PROGRAM OFFICE



# 2014 WINNER

## Localizing Ground-Penetrating Radar

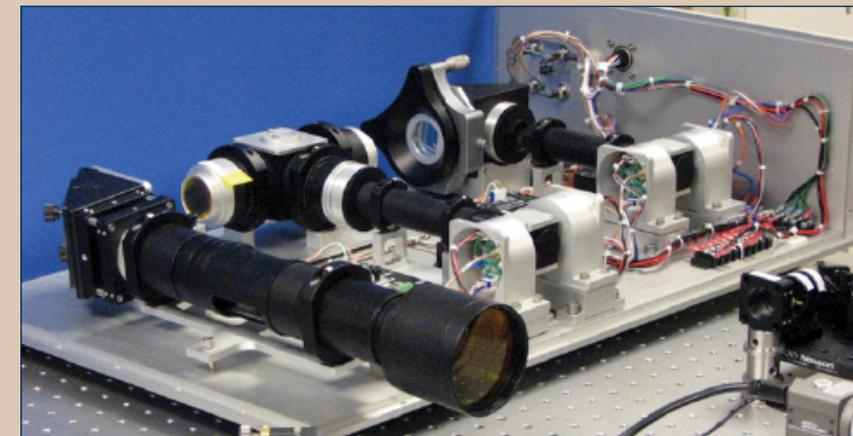
A robust sensor that provides highly accurate, real-time vehicular position estimates based on prior mapping of subsurface features



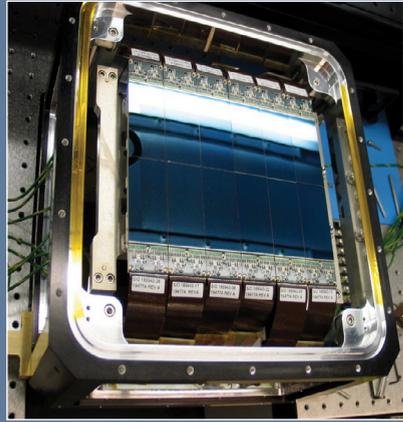
# 2014 WINNER

## Wide-Area Chemical Sensor

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







2012  
WINNER

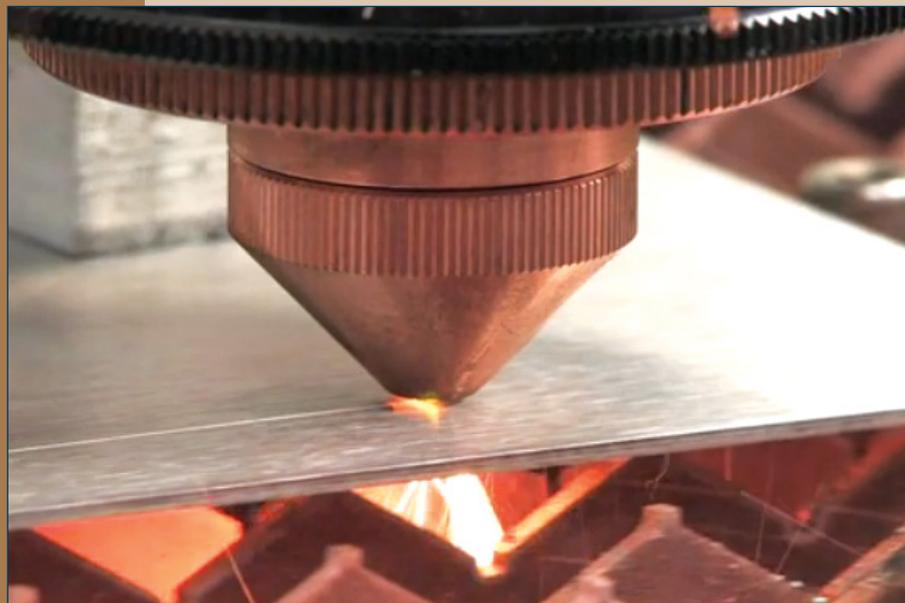
### Wide Field-of-View Curved Focal Plane Array

A curved, charge-coupled device that corrects for inherent aberrations of the mirrors and lenses in optical systems

CODEVELOPERS: STAFF FROM GL SCIENTIFIC

2012  
WINNER

### Wavelength Beam-Combining Fiber-Coupled Diode Laser



A high-intensity diode laser that combines unprecedented brightness, efficiency, and reliability

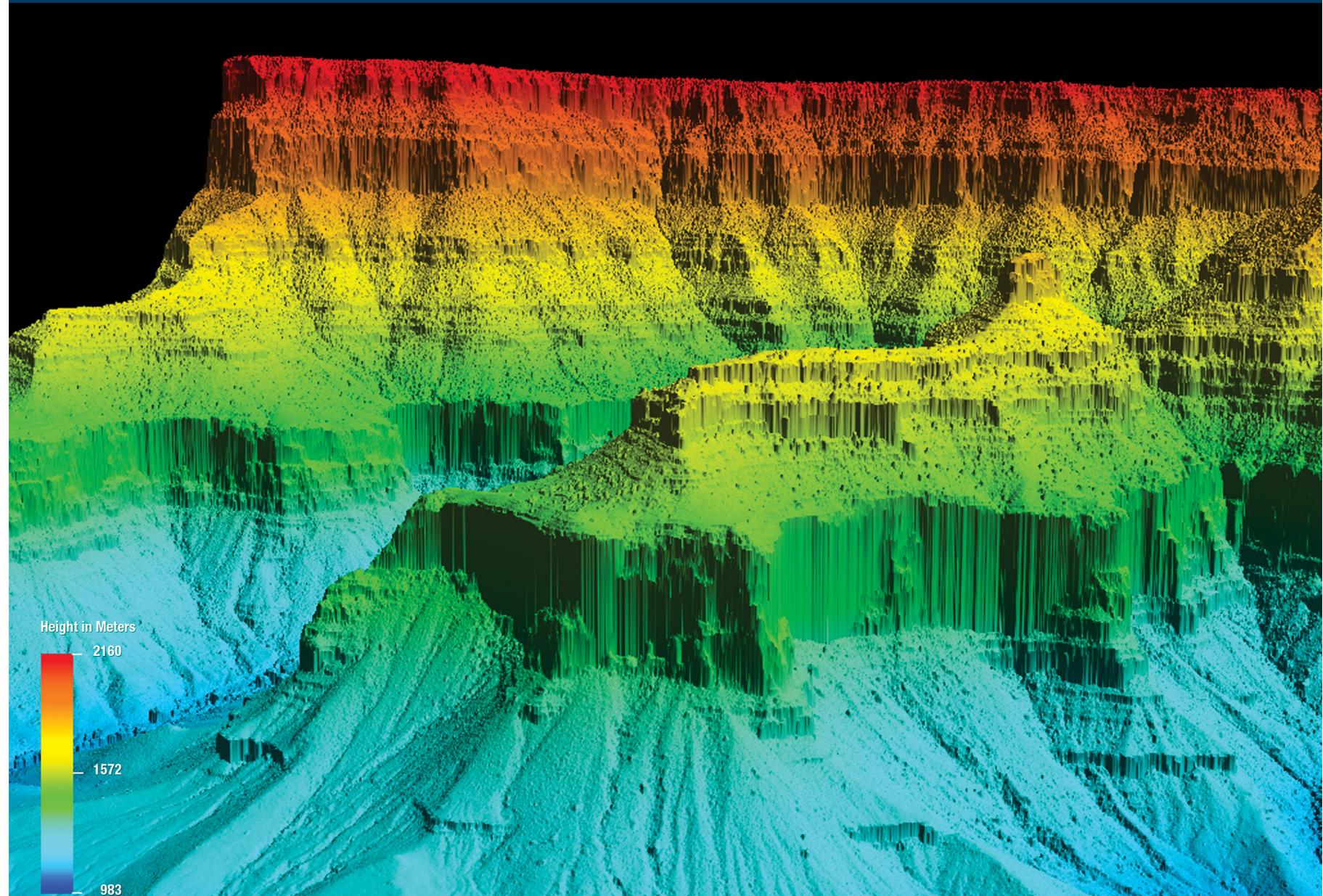
CODEVELOPERS: STAFF FROM TERADIODE

### Airborne Ladar Imaging Research Testbed

2011  
WINNER

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

CODEVELOPERS: STAFF FROM SUNSHINE AERO INDUSTRIES



**EDITOR'S CHOICE AWARD WINNER**

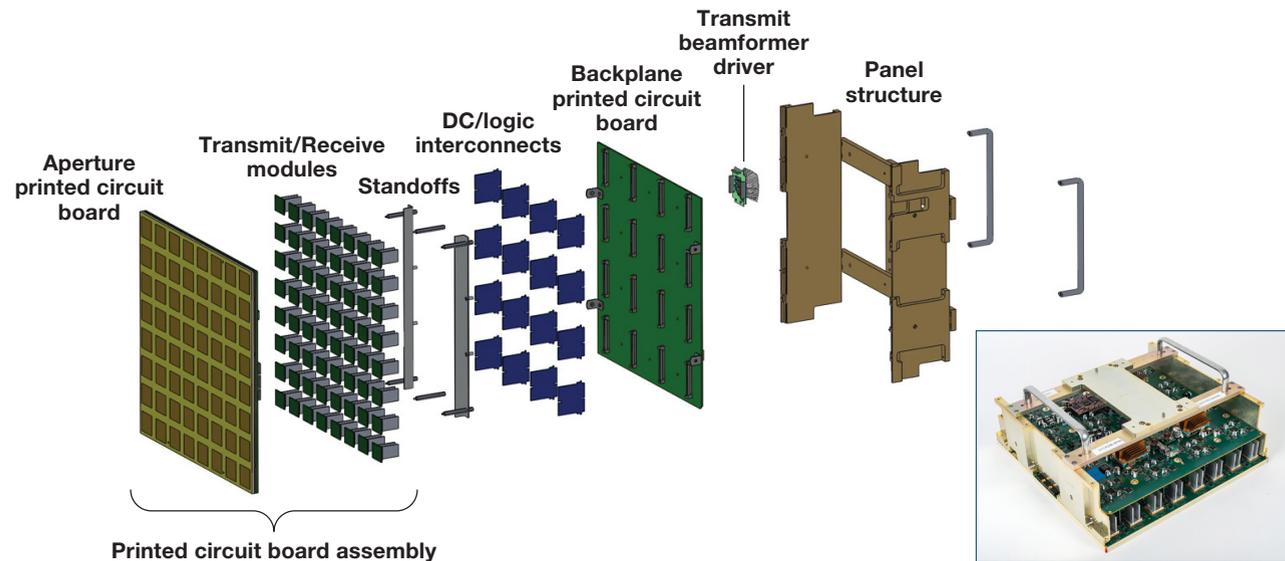
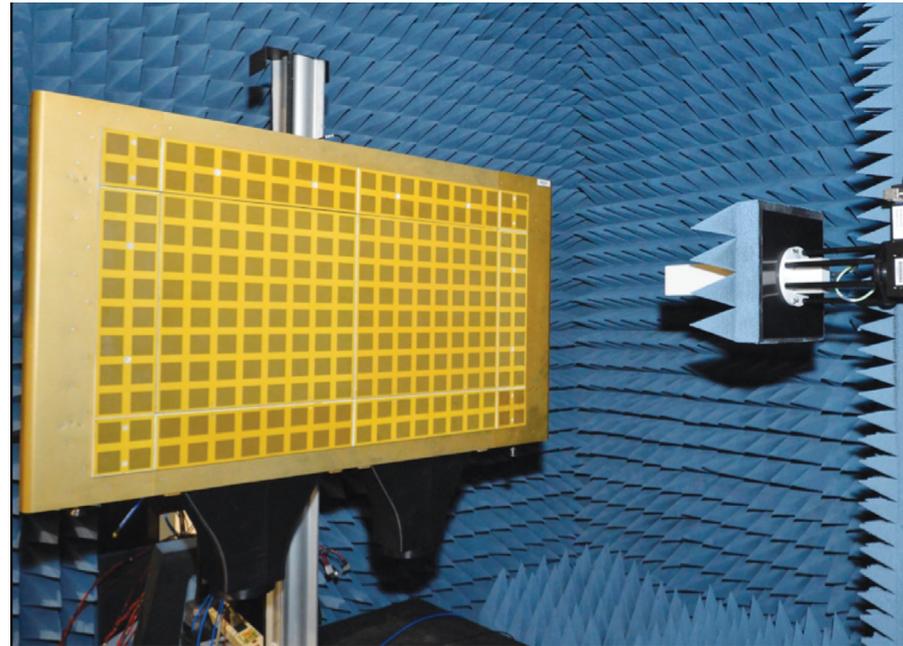
*This technology was also the winner of an R&D Editor's Choice Award, which is given to the three R&D 100 Award winners that the magazine's editors believe are the most innovative and impactful*

**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



User interface

**PVTOL**  
Functions as middleware

vector/matrix	computation	conduit	task	Reusability
□	(FFT)	→	□	
grid	map	distribution		Scalability
⊙	📄	📄		
math kernel (VSIPL++)	messaging kernel (MPI)			Portability

Hardware interface

**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

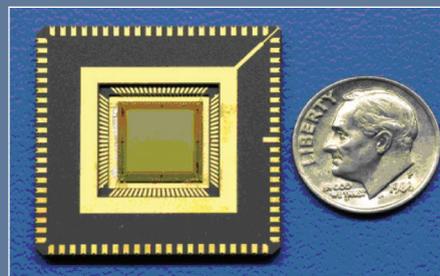
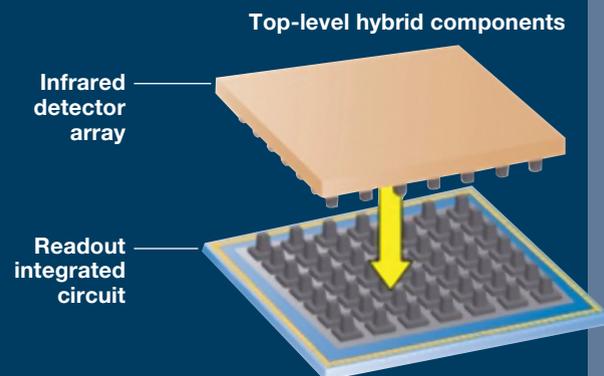
**Pathogen Analyzer for Threatening Environmental Releases**

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

2010  
WINNER

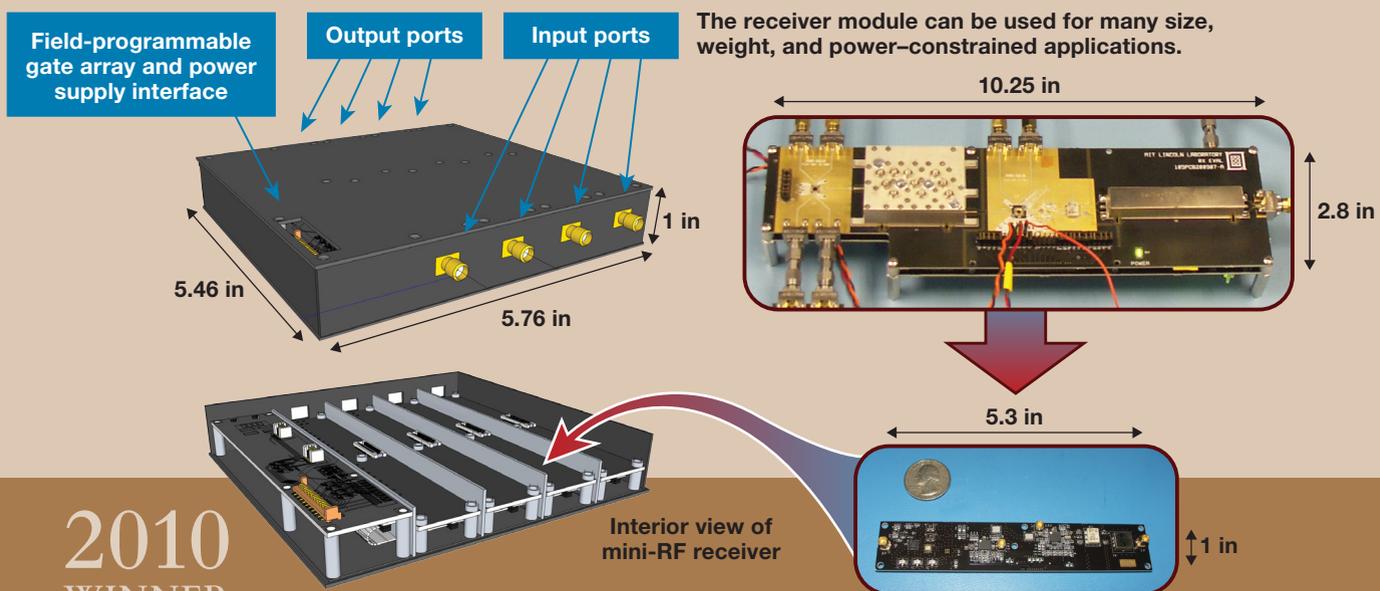
## Digital-Pixel Focal Plane Array

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

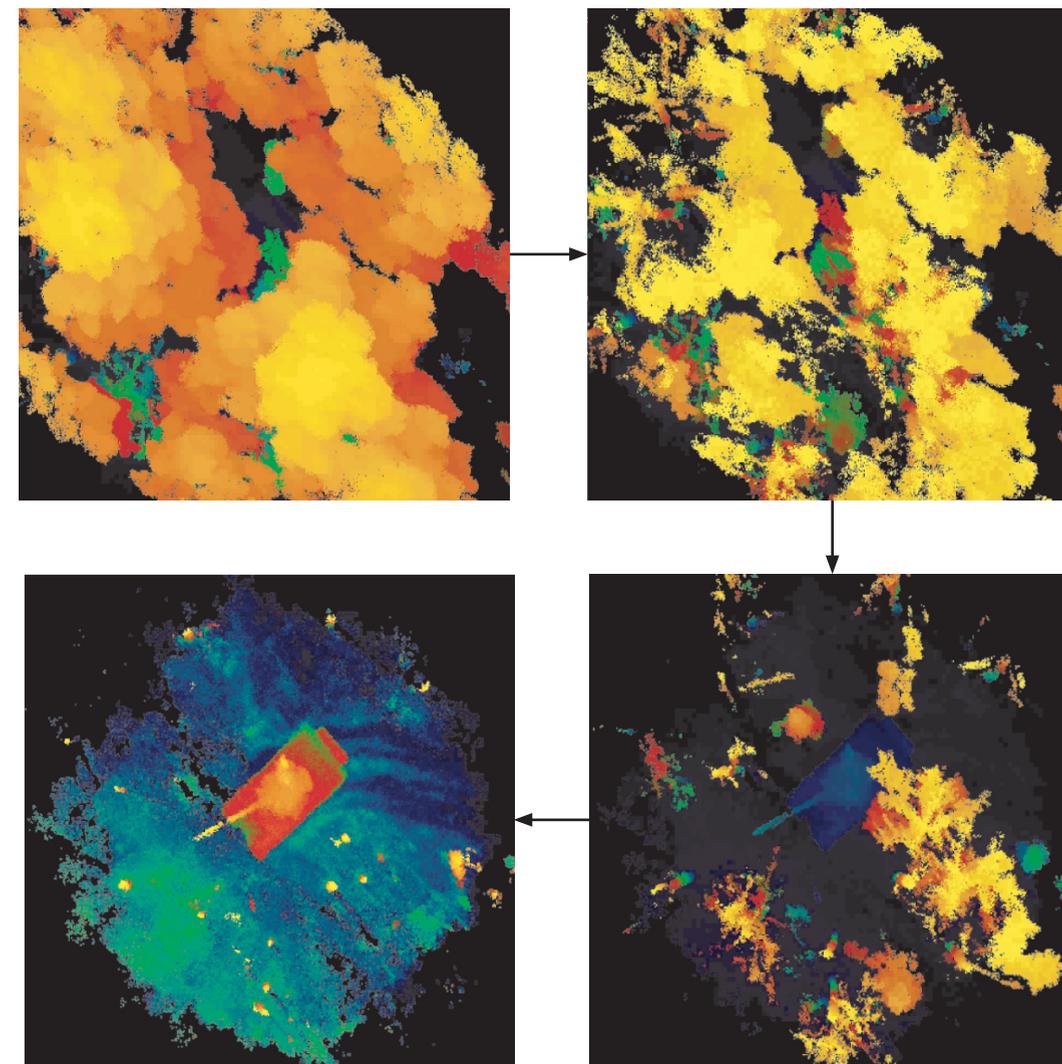
The smallest, least power-demanding receiver that can detect frequencies over a six-octave range



2010  
WINNER

## 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



2010  
WINNER

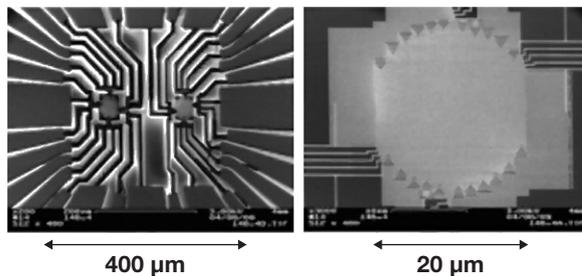
## Runway Status Lights

A system integrating data from airport surveillance sources to control in-pavement lights that directly alert pilots to potential runway incursions



2010  
WINNER

## Subwavelength-Separated Superconducting Nanowire Single-Photon Detector Array



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

CODEVELOPERS: RESEARCHERS FROM MIT

## Earlier R&D 100 Award Winners

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

**1998** jointly with Cyra Technologies and 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

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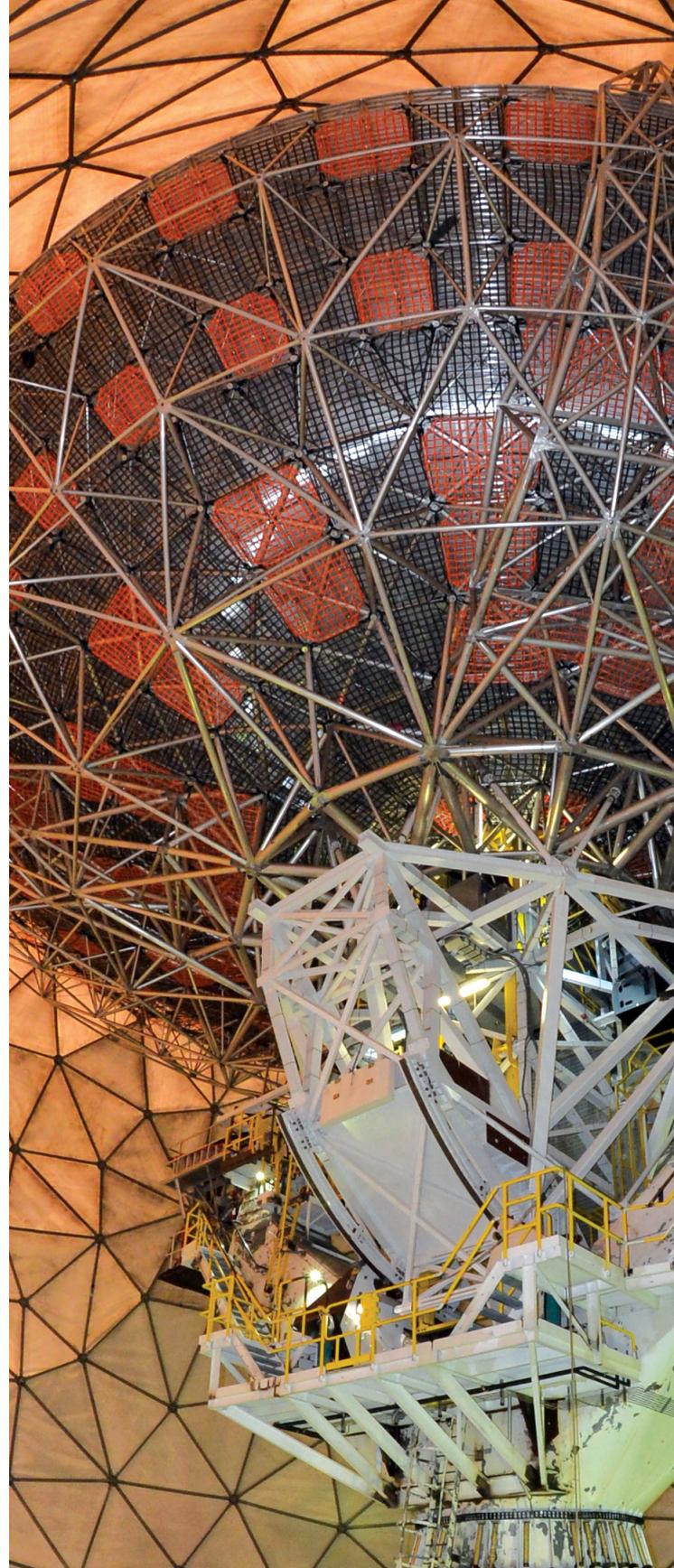
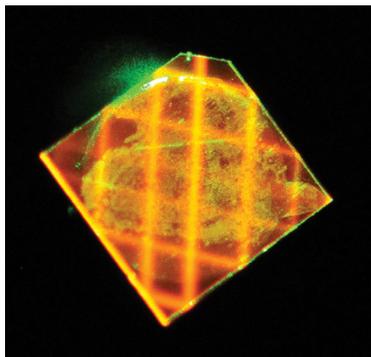
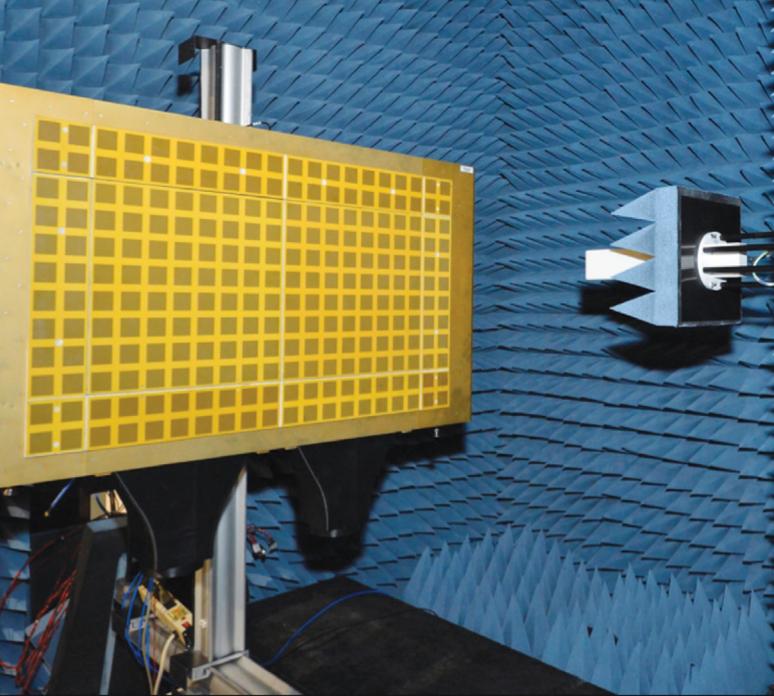
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