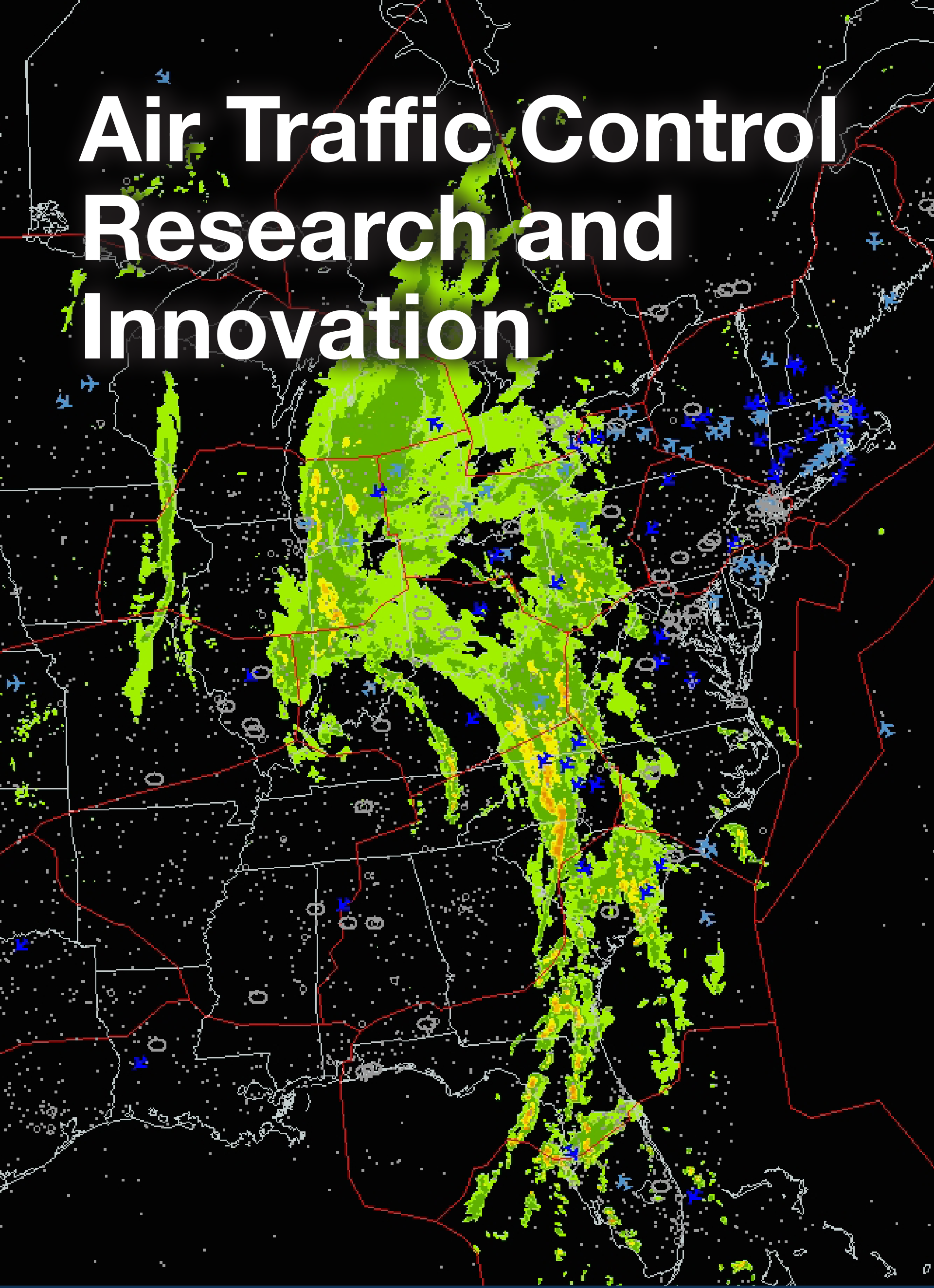
Air Traffic Control Research and Innovation



LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

About MIT Lincoln Laboratory

MIT Lincoln Laboratory was established in 1951 as a Department of Defense (DoD) Federally Funded Research and Development Center (FFRDC) focused on the development and prototyping of new technologies and capabilities to meet national security needs. Principal core competencies are in sensors, information extraction, communications, and decision support. Program activities extend from fundamental investigations through design and field testing of prototype systems using new technologies.

Lincoln Laboratory is operated by MIT, and reports to the Office of the President at the MIT campus in Cambridge, MA. The main facility is located in Lexington, MA. Lincoln Laboratory currently employs more than 3900 employees across multiple divisions: Air, Missile, and Maritime Defense Technology; Homeland Protection and Air Traffic Control; Cyber Security and Information Sciences; Communication Systems; Engineering; Advanced Technology; Space Systems and Technology; and Intelligence, Surveillance and Reconnaissance Systems and Technology.

ATC History at Lincoln Laboratory

Lincoln Laboratory has made major contributions to Air Traffic Control (ATC) technologies since 1970.

A few key prototype technology transfer examples are given below:

Mode S Beacon Surveillance

- Unisys produced 135 for major U.S. airports
- Basis for TCAS and ADS-B 1090ES

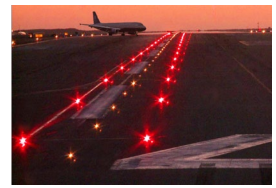
TCAS

- Produced internationally
- Mandated on over 20,000 aircraft

ASR-9 Primary Radar (WSP & 9-PAC)

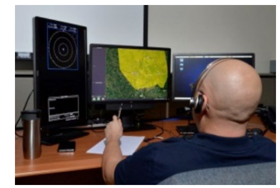
- Northrop Grumman produced 135 for major U.S. airports

Runway Status Lights



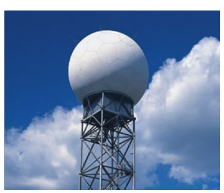
- Saab Sensis deploying to 17 airports

Ground-Based Sense and Avoid



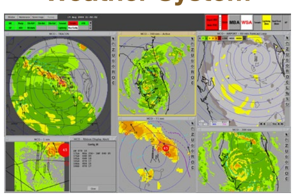
- DoD is deploying to 7 UAS sites

Terminal Doppler Weather Radar



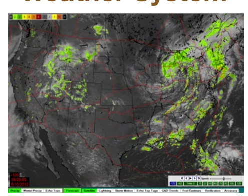
- Raytheon produced 45 for U.S. airports at highest risk for wind shear hazard

Integrated Terminal Weather System



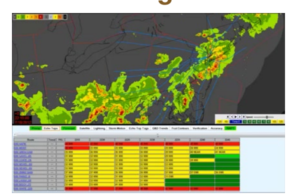
- Raytheon produced 35 systems covering 45 airports

Corridor Integrated Weather System



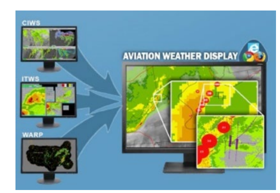
- First operational SWIM Segment 1 capability

Route Availability Planning Tool



- Deployed to TFMS at Chicago, Philadelphia, Potomac, New York

NextGen Weather Processor and CSS-Wx



- Raytheon and Harris deployment starting 2019

TCAS = Traffic Alert and Collision Avoidance System
ADS-B = Automatic Dependent Surveillance-Broadcast
WSP = Weather System Processor
PAC = Processor Augmentation Card

UAS = Unmanned Aircraft System
TFMS = Traffic Flow Management System
SWIM = System Wide Information Management
CSS-Wx = Common Support Services – Weather

Current ATC Activities at Lincoln Laboratory

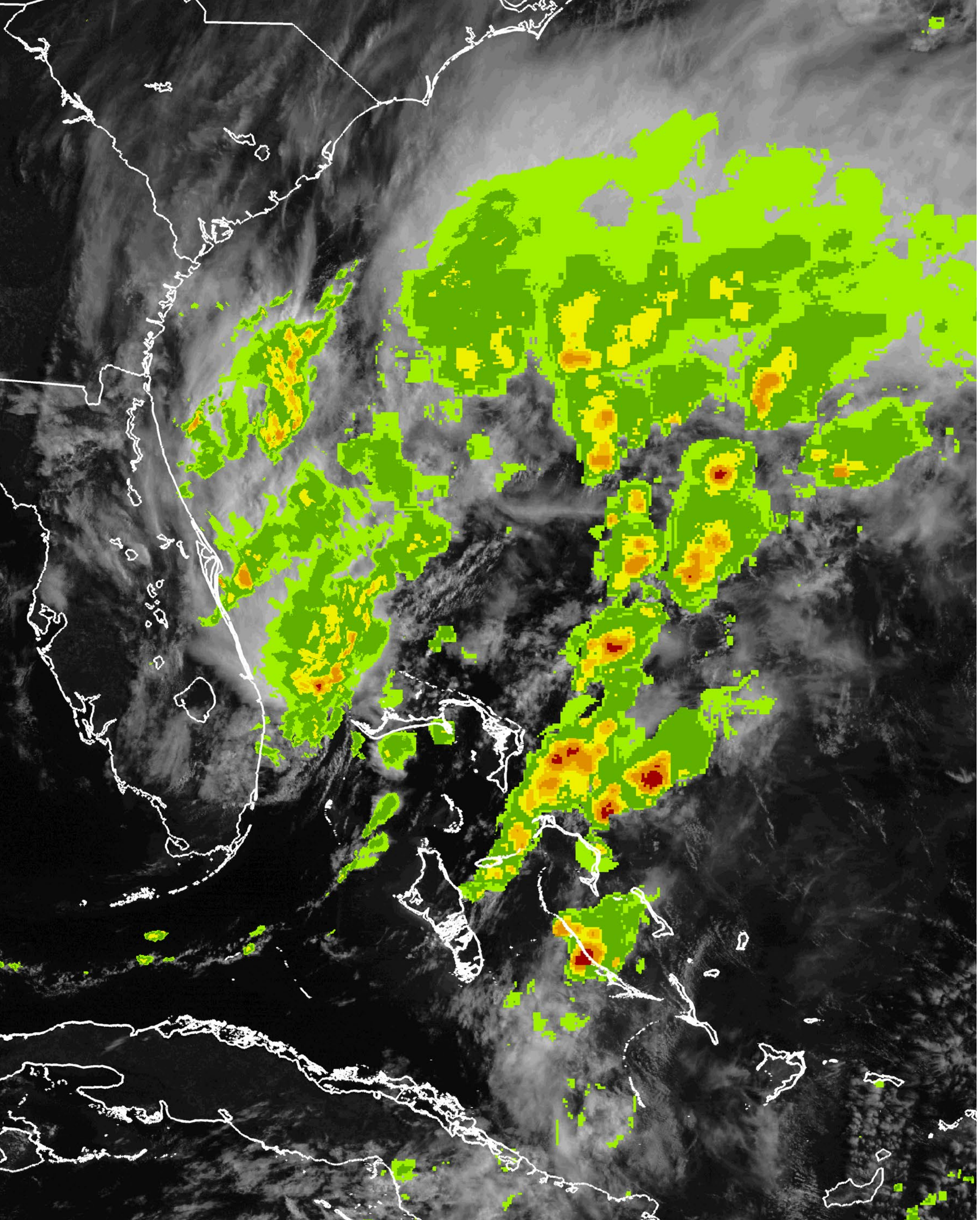
Core areas include:

- Weather Sensing
- Weather Algorithms and Forecasting
- Decision Support
- Systems Analysis
- Architectures and Cybersecurity
- Collision Avoidance
- Unmanned Aircraft System Integration
- Surveillance Systems

Weather Sensing

Lincoln Laboratory has supported the Federal Aviation Administration (FAA) in the development and enhancement of multiple weather radar systems. These include the Terminal Doppler Weather Radar (TDWR), developed in response to wind shear accidents, and the nation's Next Generation Weather Radar (NEXRAD) network, which was developed through multiagency coordination between the FAA, National Weather Service (NWS), and DoD.

Advanced algorithms are under development that leverage the new NEXRAD dual polarization capability to reduce clutter, classify hydrometeors, and identify hazardous regions of hail and icing. Using Lincoln Laboratory's evaluation infrastructure, researchers thoroughly test the algorithms across a range of environments, and then the algorithms are transitioned approximately every 18 months to the NEXRAD Radar Operations Center for deployment nationally.



Weather Algorithms and Forecasting

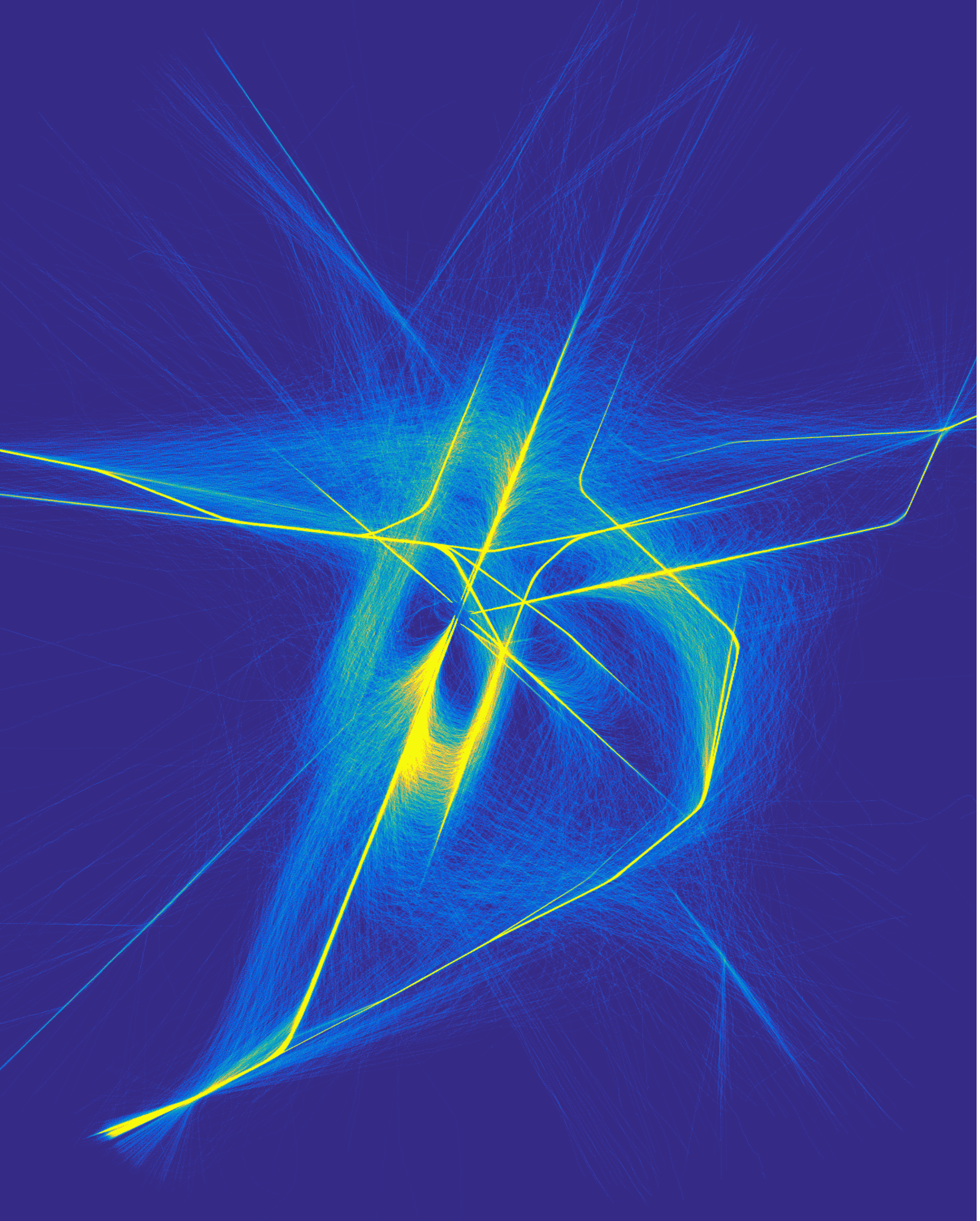
Lincoln Laboratory has developed a range of weather algorithms and forecasts tailored for different ATC needs. The Corridor Integrated Weather System (CIWS) is a 0–2 hour forecast product supporting tactical decisions and is operational in many major U.S. ATC facilities. The prototype Consolidated Storm Prediction for Aviation (CoSPA) tool provides a 2–8 hour forecast for more strategic traffic management decisions. The technologies behind CIWS and CoSPA will soon be subsumed into the NextGen Weather Processor (NWP), also developed by Lincoln Laboratory.

The Offshore Precipitation Capability (OPC) uses advanced machine-learning technology to provide ATC with radar-like weather situational awareness even in areas beyond the reach of land-based weather radars. OPC is currently running as an operational prototype at several FAA facilities.

Decision Support

Lincoln Laboratory develops tools to translate weather forecasts into air traffic impacts to support effective controller and traffic manager decision making. The Route Availability Planning Tool (RAPT) overlays current and forecast weather on air traffic routes around airports to indicate where and when routes may be impacted. These concepts are being extended to terminal and en route airspace in the Traffic Flow Impact (TFI) tool, which is currently a prototype capability provided by CoSPA.

Other tools are being designed to support advanced air traffic tower operations, increase capacity at airports with closely spaced parallel runways using wake turbulence mitigation procedures, and estimating airport acceptance rates to support traffic management planning.



Systems Analysis

Lincoln Laboratory conducts systems analysis activities to better understand ATC dynamics, to quantify system performance, and to undertake benefits assessment to inform proposed improvements.

Analyses examine operational inefficiencies and develop near-term enhancements in every flight phase to reduce fuel burn and mitigate environmental impacts. Aviation network analyses leverage big data approaches to better understand system dynamics (e.g., how delay propagates through the system) at a range of spatial and temporal scales. Serious gaming tools are also being developed to accelerate the training of traffic management best practices and to provide “what if” execution capabilities.

Architectures and Cybersecurity

Lincoln Laboratory is developing foundational architectures to enhance and protect ATC infrastructures.

The NextGen Weather Processor (NWP) consolidates multiple FAA weather systems into a single platform to ensure a common weather picture for all ATC stakeholders. NWP will leverage Common Support Services – Weather (CSS-Wx), System Wide Information Management (SWIM), and other data exchange capabilities in development at Lincoln Laboratory.

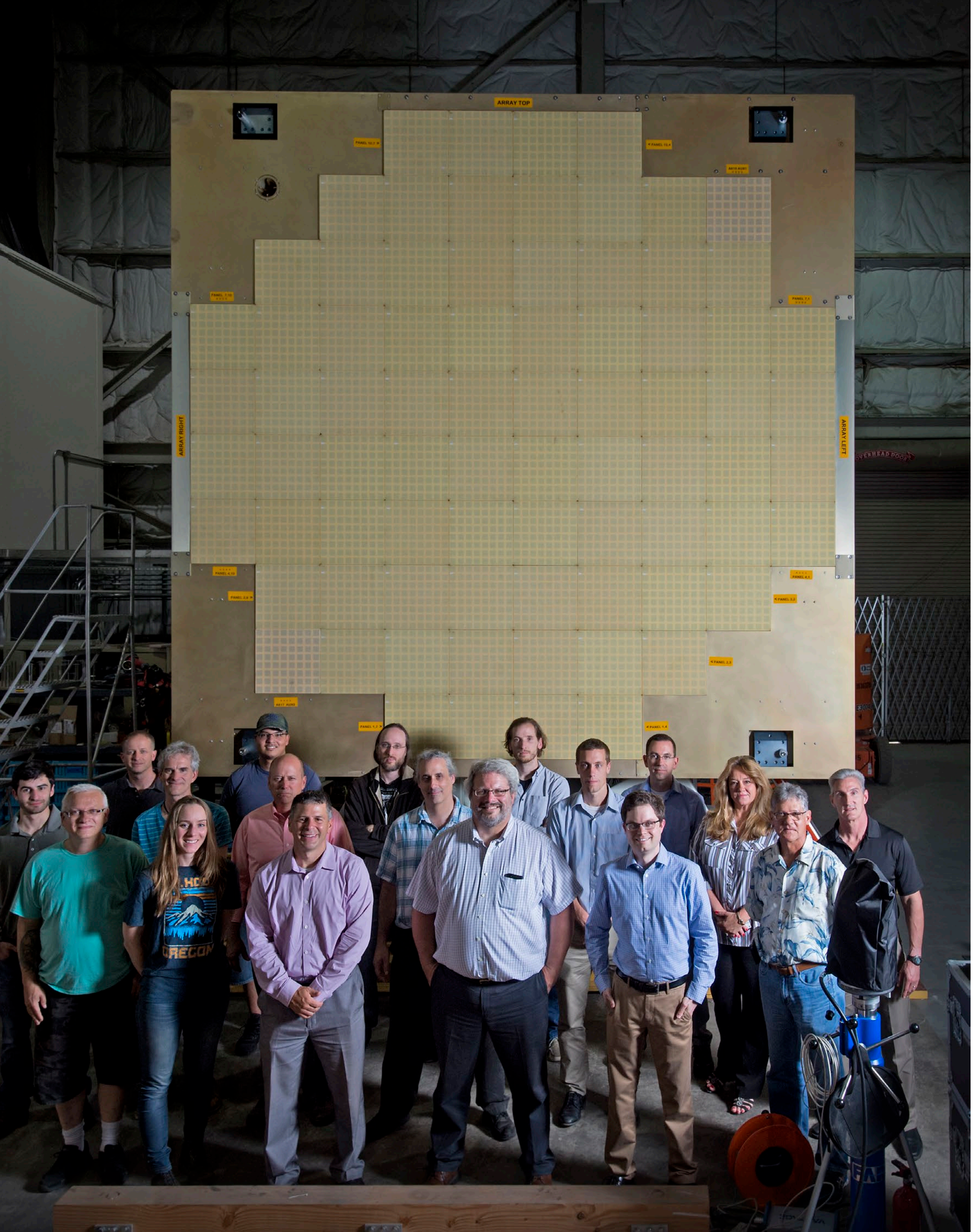
Lincoln Laboratory is also playing a key role in the emerging field of aviation cybersecurity, analyzing risks and evaluating potential mitigations that could be used to help protect aircraft systems from attack, and also demonstrating advanced big data analytics that could be used to help protect FAA systems and networks.

Collision Avoidance

Since the 1980s, Lincoln Laboratory has supported the FAA in the development of the existing Traffic Alert and Collision Avoidance System (TCAS). Lincoln Laboratory is now developing the surveillance processing and alerting algorithms for the next-generation Airborne Collision Avoidance System (ACAS X) for both manned and unmanned aircraft. Lincoln Laboratory's capabilities include high-fidelity airspace encounter models and simulation infrastructure leveraging the Lincoln Laboratory Supercomputing Center to enable broad statistical safety analyses. Novel algorithms for ACAS X have been implemented based on Markov Decision Processes (MDPs) and dynamic programming, resulting in a system that adapts to sensor and dynamic uncertainties to reduce nuisance alert rates while also improving safety.

Unmanned Aircraft System Integration

Lincoln Laboratory is supporting the integration of Unmanned Aircraft Systems (UAS) into civil airspace. Programs involve modeling, simulation, and flight test capabilities, systems analysis, development of safety standards, and validation of sensor and algorithm performance requirements. Prototype systems have been developed and evaluated for Ground-Based Sense and Avoid (GBSAA) and Airborne Sense and Avoid (ABSAA). Flight tests of ACAS Xu (a variant for UAS vehicles) have demonstrated the capability of UAS to maneuver autonomously, both vertically and horizontally, based on a variety of surveillance sources, including transponders, Automatic Dependent Surveillance-Broadcast (ADS-B), airborne radar, and electro-optical systems.

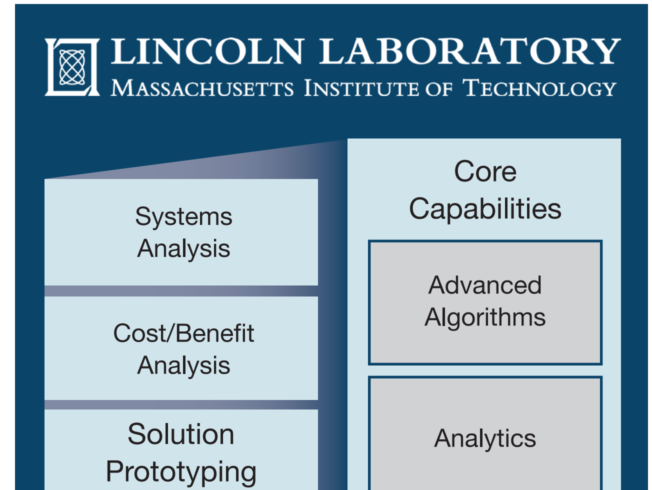


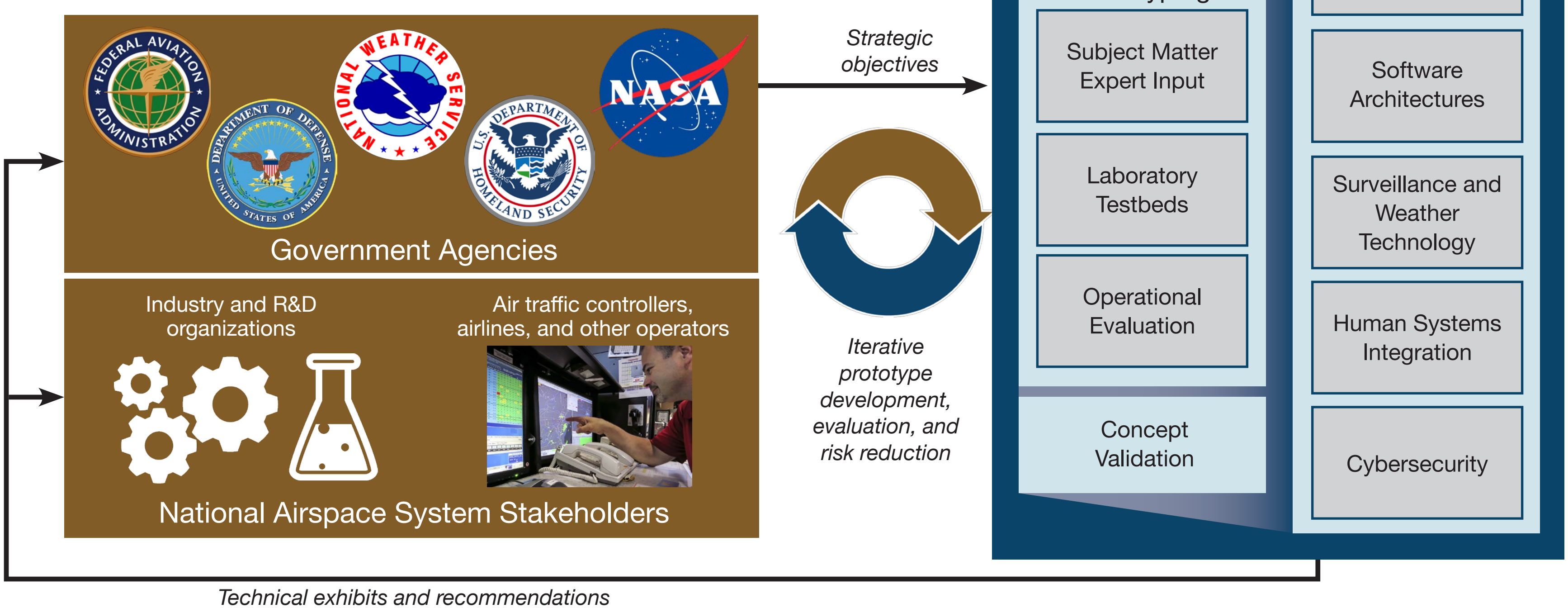
Surveillance Systems

Technologies for lower-cost, high-performance surveillance systems are being developed for surface, terminal, and en route applications. The prototype Multifunction Phased Array Radar (MPAR) Advanced Technology Demonstrator (ATD) is being used to assess the potential for lower-cost phased array technologies to perform air and weather surveillance missions. Other analyses are evaluating the performance of ADS-B and associated requirements to enable more efficient NextGen procedures such as Interval Management, or operations under reduced separation minima.

How Lincoln Laboratory Is Helping

Lincoln Laboratory works closely with air transportation system stakeholders to understand their strategic goals and operational needs. Lincoln Laboratory uses these collaborations to identify problems and diagnose causes, and applies its core technical capabilities to develop solutions that address user needs and improve system operation. Through a focused technology transfer process, these prototype solutions are then transitioned to the government and industry for larger-scale operational deployment.

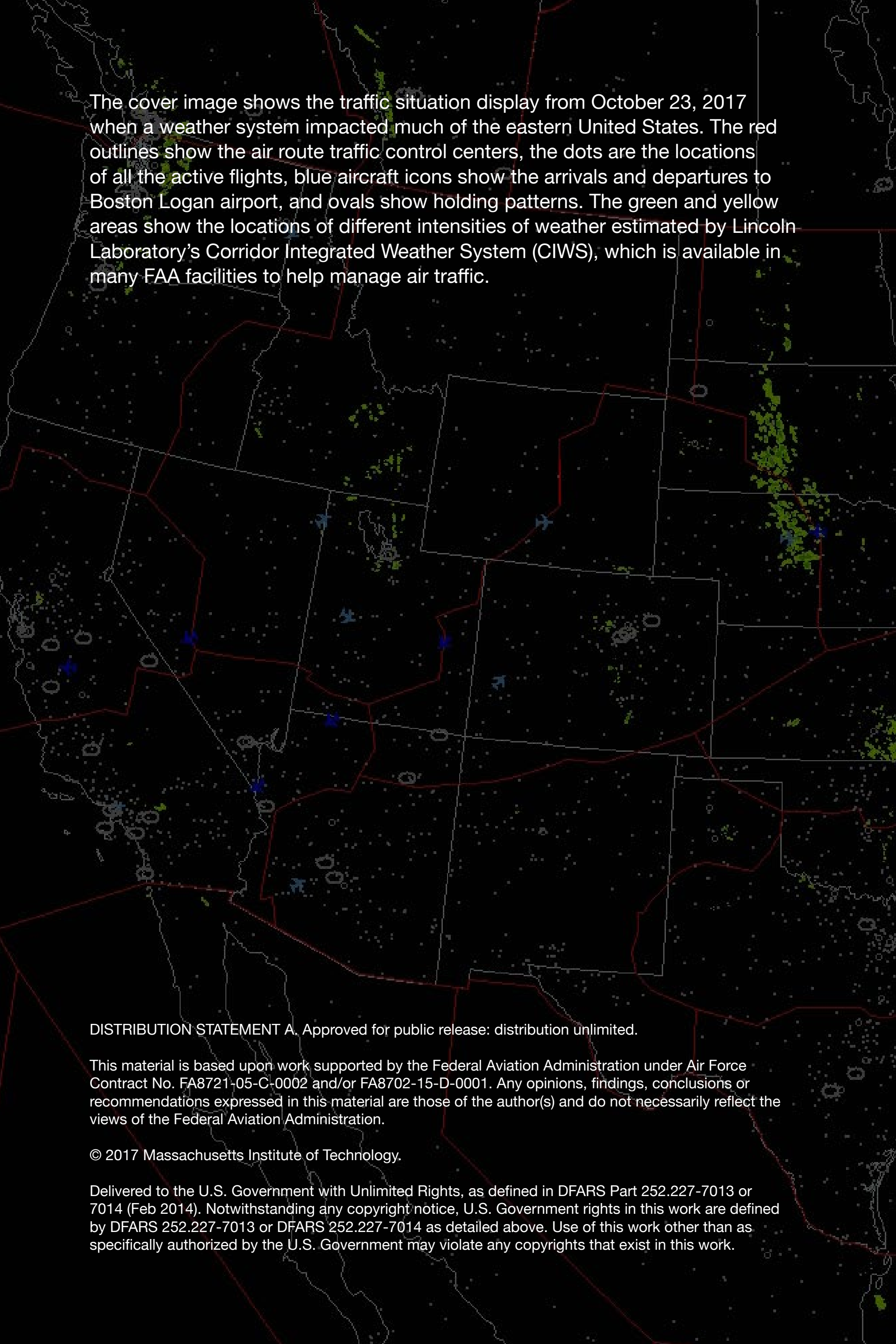




Further Information

Further information and more detailed descriptions of core capabilities can be found at www.ll.mit.edu.

For questions and inquiries on Lincoln Laboratory's ATC activities, please contact us at ATC@ll.mit.edu.



The cover image shows the traffic situation display from October 23, 2017 when a weather system impacted much of the eastern United States. The red outlines show the air route traffic control centers, the dots are the locations of all the active flights, blue aircraft icons show the arrivals and departures to Boston Logan airport, and ovals show holding patterns. The green and yellow areas show the locations of different intensities of weather estimated by Lincoln Laboratory's Corridor Integrated Weather System (CIWS), which is available in many FAA facilities to help manage air traffic.

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