MITRE Asia Pacific Singapore:
A Retrospective of Impact

MITRE

Introduction

Partners in Innovation

Singapore is described as one of Asia's four economic tigers, with sustained, exponential growth in recent decades. A leader in free-market innovation in the Asia-Pacific region, Singapore is a singular location for research and development in a variety of domains.

For over 65 years, MITRE has worked in the public interest by delivering objective, leading-edge solutions to many of the world's biggest challenges by putting research to work. When the opportunity to partner with the Civil Aviation Authority of Singapore (CAAS) presented itself, it was a natural fit.

MITRE has a long history of partnership with CAAS that started in the 1990s and focused on improving flow management and optimizing runway capacity. As a result of continued impact, MITRE Asia Pacific Singapore (MAPS) was established in 2014. It was designed to facilitate a long-term, collaborative program of research, development, and technology transition to support regional harmonization in aviation and transportation in the Asia Pacific region. It is MITRE's first R&D center outside of the United States, and when it opened, it was the first of its kind in the Asia Pacific Region.

MITRE's long-standing aviation work program in the region provided a foundational understanding of the complexity and growing demand in Singapore. IATA and other organizations have predicted that by 2040, nearly 50% of the world's traffic will fly through Asia Pacific. Singapore is positioning itself as the hub that will serve this influx of passenger traffic.

Today, with CAAS' vision and partnership, and with the support of the United States Federal Aviation Administration (FAA), MAPS is an essential part of the global aviation R&D ecosystem. With strong partnerships across the region, MAPS is charged with sharing knowledge to enable the effective and rapid transfer of technology to local institutions. In addition, in the last decade, Singaporean engineers have worked and trained closely with U.S. aviation experts to prepare for positions in global aviation groups, including CAAS, Changi Airport Group, Thales, and others.

This retrospective of the last decade provides an overview of MITRE's partnership with CAAS, their shared accomplishments and key operational highlights, and offers a glimpse at what's next.

Section 1:
A Global Aviation Mission

As a global leader, the FAA works with international organizations to promote aviation safety and efficiency for the worldwide alignment of technologies, policies, regulations, and standards. In collaboration with partners around the world, the FAA's work plays an essential role in resolving current challenges to global aviation and forging the future direction of the industry, including safety, cybersecurity, innovation, sustainability, and training.

MITRE's work with the FAA began in 1958 when MITRE was founded and civil aviation in the U.S. was born. In 1990, the FAA formally established a federally funded research and development center (FFRDC) for MITRE to operate: the Center for Advanced Aviation System Development (CAASD). Since then, MITRE has been on the forefront of groundbreaking advances in aviation.

It is with the FAA's approval and guidance that MITRE established an international aviation program to support the FAA mission of having the safest, most efficient aerospace system in the world. MITRE is encouraged to undertake engineering research and development efforts for international civil aviation authorities, or like organizations, to advance, among other things, international harmonization of aviation standards and technology. MITRE focuses on specialized work normally not covered by the consulting world or work requiring impartiality rarely found in other venues.

MITRE's work in the Asia Pacific region started with civil authorities in Singapore, India, Japan, Korea, and Vietnam. Singapore's role as an aviation hub in the region and a leader in innovation made it an attractive partner to MITRE. With CAAS' vision to be a leader in civil aviation connecting the world, Singapore was the ideal location for MITRE to support CAAS' mission for growing a safe, vibrant air hub and system while also supporting the FAA's goals of global harmonization.

> Because MITRE owns the Intellectual Property (IP) it develops, it has been able to buy down the risk of research and bring already developed and proven technologies to CAAS. In return, MITRE shares the benefits from new IP created in Singapore with its U.S. FAA sponsor in support of global harmonization.
>
> ***— Dr. Kerry Buckley, Vice President Center for Integrated Transportation, MITRE***

Attributes of MITRE's International Aviation Program

- Maintain close connections with the senior leadership, typically at the Director General level
- Operate by establishing long-term relationships and providing independent, objective, data-driven recommendations on our customers' most important challenges
- Make effective use of rigorous data-driven methods and immersive technologies, including human-in-the-loop experimentation, through MITRE's integrated laboratories
- Actively participate in the International Civil Aviation Organization (ICAO) and the Civil Air Navigation Services Organization (CANSO)
- Work with organizations to help develop aviation system standards that are compatible with U.S. standards.

An Integrated Facility

MAPS is a 10,000-square-foot facility that features MITRE-developed real-time and fast-time simulation tools, which comprise a fully connected cockpit simulator, wrap-around tower, area and approach air traffic controller workstations, with advanced traffic-flow management tools. Highly adaptable, each of these components can be reconfigured and integrated with partner facilities for end-to-end integration and consensus building across a diverse set of stakeholders and remote locations.

The lab also offers a collaborative research environment, from human-in-the-loop (HITL) experimentation to immersive simulations with virtual connectivity to the broader transportation stakeholder community. MITRE's extensive network of U.S. lab capabilities can also be utilized for MAPS to meet sponsor needs.

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The lab provides an environment for all parties to share the experience of a proposed concept change and vet ideas to mature the capabilities. It also gives stakeholders an opportunity to discuss their concerns on a variety of issues. This is a place to gain consensus among key stakeholders—not only for MITRE-developed technology, but for capabilities from other research organizations, industry and academia as well.

— ***Tass Hudak, former MAPS Site Leader, MITRE***

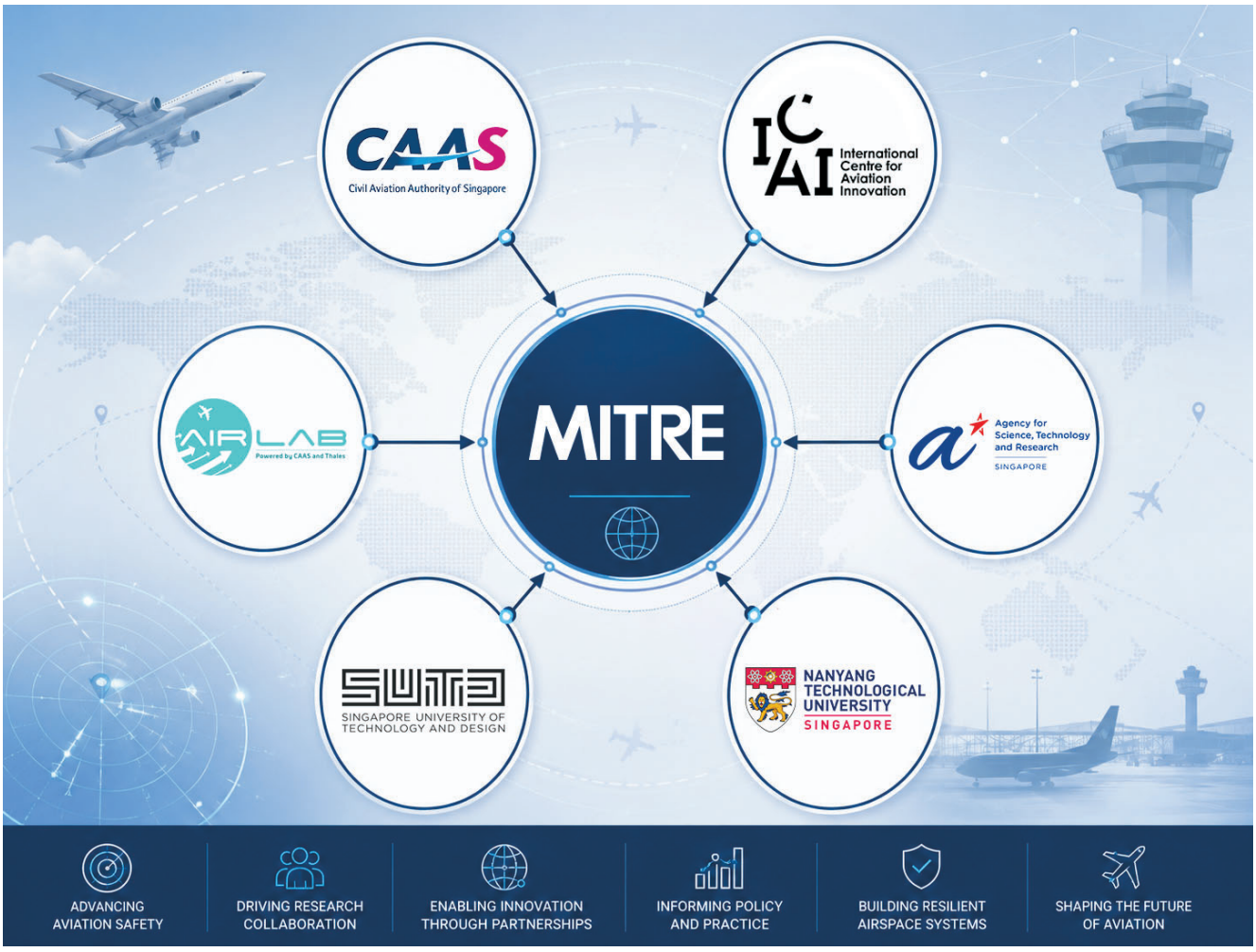
Changi Airport Runway Expansion:

As part of a multi-year development to add a fifth terminal and third runway, plus a remote air traffic tower, Changi Airport’s expansion sought to transform every aspect of airport operations. MITRE conducted research and simulations that demonstrated how expanded operations would be safe and efficient. Working across MAPS and MITRE’s McLean, Virginia, laboratories, required intense logistics and planning, with high levels of agility and precision to help the plans surpass rigorous safety thresholds. The collaborative effort combined air traffic controllers from CAAS and MITRE’s expertise in maximizing the use of three-runway operations and design of procedures for complex flight information regions.

Growing Singapore's Aviation Ecosystem

A fundamental pillar of MITRE's work in Singapore is to work with local talent to train and prepare them to be the next generation of aviation leaders in Singapore. Since establishing MAPS, Singaporean MITRE Global Employees have moved on to serve in the aviation ecosystem.

MAPS was also chartered to ensure knowledge and technology transfer to local research institutes and has established strong partnerships with Singaporean research and development partners, including the Agency for Science and Technology Research (ASTAR), International Centre for Aviation Innovation (ICAI), and others.



A Proven Track Record

Since opening in 2014, MAPS has been on the front lines of air traffic efficiency, airport expansion, aviation safety, and turbulence mitigation for Singapore and the region.

MAPS: 12 Years of Impact

Products that have been implemented, planned for implementation, or tech transferred

- **What-if Capability** — Tech Transferred
- **Single Monitor Ops** — Implemented
- **Conflict Resolution Tool** — Tech Transferred
- **Departure Spacing Tool** — Planned for Implementation
- **Obstacle Limitation Surfaces** — Implemented
- **Automated Terminal Proximity Alert (ATPA)** — Tech Transferred
- **Flight and Flow Information (FF-ICE)** — Planned for Implementation
- **Air Traffic Management Center** — Planned for Implementation

> Singapore has long led Asia Pacific in growth and planning, so it was a logical fit for MITRE to partner with CAAS to amplify R&D for the benefit of the entire region.
>
> ***— Dr. Juliana Goh, former MAPS Site Leader, MITRE***

Section 2: Operational Highlights

Safety

Merging and Spacing: MITRE conducted a study of two tools—Automated Terminal Proximity Alert (APTA), and Relative Position Indicator, a conceptual prototype developed by MITRE. The objective was to determine the controller acceptability and potential benefits of these merging and spacing tools through HITL simulations conducted at MAPS. This work resulted in CAAS sharing the tool with their current Air Traffic Management system provider, Thales, with Thales developing a similar tool for CAAS. This is currently being used in operations.

Air Traffic Management Meteorology Integration Solutions: MITRE developed a suite of three different tools for convective weather prediction and tail wind prediction:

1. Convective Weather Impact Forecast (CWIF) Enroute
2. CWIF Approach
3. Storm-Induced Runway Reconfiguration Management (STIRR-M).

The dynamic nature of convective weather in Singapore presents a persistent challenge for air traffic operations, particularly in scenarios involving low-altitude holding and rapidly changing weather conditions. These constraints can lead to inefficiencies, increased delays, and safety risks. MITRE engineers have developed integrated Meteorology–Air Traffic Management solutions for the Area Control Centre, Terminal Maneuvering Area, and Aerodrome operations through the CWIF program to enhance situational awareness and weather-related decision support. These tools leverage Japanese weather satellite, Singaporean weather radar, and wind observations, along with flight trajectory data to identify the types of weather encounters likely to be most disruptive to air traffic. Using both artificial intelligence and physics-based models, CWIF predicts locations of impactful weather up to 8 hours in the future. That information can be used by traffic flow managers to enable a transition from tactical to strategic weather-related decision making from when to change runway configuration to when to impose traffic management initiatives.

CWIF Enroute is currently being used by the CAAS Air Traffic Flow Management Unit for daily constraint coordination with neighboring Air Navigation Service Providers. This work was also technology and knowledge transferred to a Singapore research partner, ASTAR, that will be working alongside MITRE to further mature these capabilities.

Ensuring Accurate Position Data: MITRE also worked on a system to ensure that pilots are receiving accurate position data from the GPS aboard their aircraft. When CAAS decided to pursue a Ground-Based Augmentation Systems (GBAS) system for Changi Airport, they first needed to capture the full range of ionospheric behavior that could affect the GBAS at Changi and then build enough safety margin into the integrity monitors to keep the system safe. MITRE installed four data-collection ground stations at the airport. Using those stations, they recorded GPS measurements for a year. They also obtained nearly two years' worth of data from the Singapore Land Authority (SLA), which operates a network of ground stations across the island nation. The combined data from the two networks provided a statistically significant picture of ionospheric variability over Changi Airport. MITRE created an ionospheric threat model for Singapore to define limits on the size and speed of the disturbances that could affect GPS reception at Changi. The work allowed CAAS to move forward on the installation and certification of a GBAS at Changi Airport, aligned with their goal to continue being at the forefront of aviation in Southeast Asia.

> MITRE's mission is in the service of public interest, and there are few things that impact every individual like aviation. It is an economic engine for the world and enables connectivity for families, friends, and businesses. It is a privilege to partner with CAAS to advance aviation safety and efficiency for Singapore and the region.
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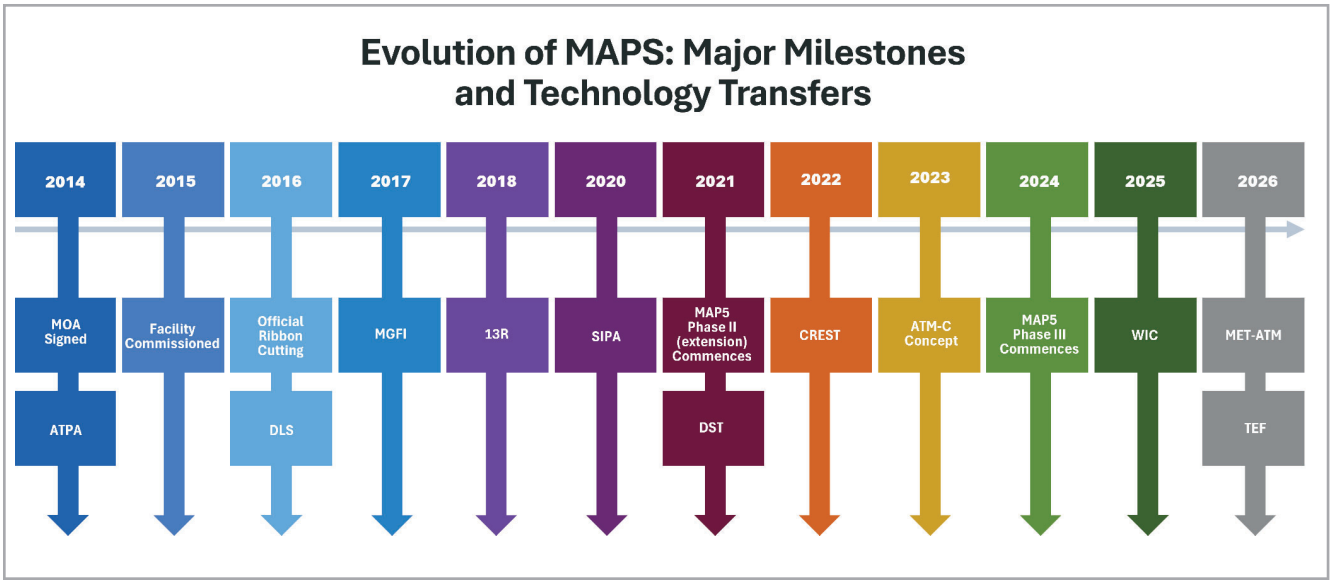
> *— **Prakash Subramanian, Managing Director, Advanced Transportation Operations & Safety, MITRE***



Efficiency

Obstacle Limitation Surfaces (OLS): MITRE developed a method for comparison of obstacle limitation surfaces near an airport to allow CAAS to assess the feasibility of modernizing them. MITRE Geographic Information Systems (GIS) expertise enabled development of an enhanced analysis methodology, with three-dimensional visualizations. This work allows Singapore to change its building code, potentially freeing millions of dollars in real estate that would have otherwise not have been possible.

Simultaneous Independent Parallel Approaches (SIPA) with a Single Monitor: MITRE demonstrated that a single monitor can safely support SIPAs at Changi (a change from the typical ICAO and FAA requirement for two monitors). This change enables a more efficient use of controller resources, increases SIPA availability, and enhances overall capacity and efficiency.

Conflict Resolution Tool (CREST): MITRE did years of research and validation on this tool, holding several HITLs and incorporating feedback from dozens of controllers. This work is now being turned into requirements/specifications that are now part of the tender for the new Air Traffic Management System that Singapore will be acquiring.

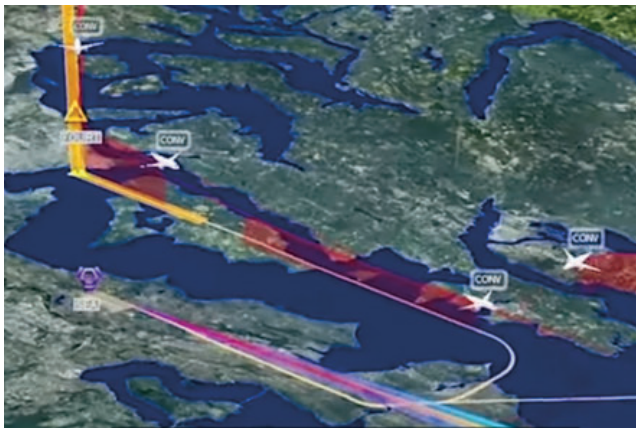
Departure Spacing Tool (DST): The DST helps the controller time the take-off clearance for the next departure aircraft so that it starts its take-off roll at the appropriate time to achieve the required time- or distance-based separation from the preceding aircraft when airborne. It presents to the controller the applicable aircraft-pair separation and a countdown to the recommended start take-off roll time, supporting more consistent and efficient spacing to optimize runway capacity. This technology is now being included as part of the requirements/specifications for the new Integrated Digital Tower System.

What-if Capability (WIC): The WIC is designed to tackle operational challenges related to identifying the best mix of strategy, solutions, and tactics for managing demand-capacity imbalances affecting air traffic within the Singapore Flight Information Regino (FIR) effectively and equitably. This allows CAAS flow planners, managers, and data analysts to integrate capacity and demand forecasts, as well as various dynamic Air Traffic Flow Management (ATFM) control measures, to assess the impact of proposed solutions within strategic, pre-tactical, tactical, and post-operation analysis timeframes. This capability facilitates a comparison of the different measures, offering valuable insight into the effects of each option on a bespoke set of throughput and delay metrics assisting the user in choosing the most optimal one. It also provides a wider perspective, extending beyond the immediate Singapore FIR and Changi airport environment, to evaluate regional and long-range ATFM measures.

This technology has been on-boarded into CAAS's Information Experimentation Platform (iEP) and planned to be experimented and trialed in CAAS' Air Traffic Flow Management Unit.

Information Experimentation Platform (iEP): MITRE partnered with CAAS and its selected industry partner, NCS, to architect, design, and establish the Information Experimentation Platform (iEP), a secure enterprise cloud platform for digital innovation, experimentation, and rapid capability development. iEP provides a common environment for integrating operational data, developing, and deploying cloud-native applications, supporting AI, advanced analytics, modeling and simulation, and evaluating new operational concepts. Beyond developing the platform, MITRE worked closely with NCS throughout the project to transfer the platform architecture, technical knowledge, and operational practices, enabling a seamless transition to local ownership. Today, NCS successfully operates and maintains iEP on behalf of CAAS, demonstrating the effectiveness of the collaboration and the sustainability of the platform. Building on this success, MITRE continues to partner with CAAS and NCS to develop and deploy increasingly advanced capabilities on iEP, including AI-enabled decision support, next-generation data products, and other strategic initiatives that expand the platform's operational value.

Flight and Flow Information for a Collaborative Environment (FF-ICE): The MITRE developed FF-ICE prototype has been used as part of several demonstrations, including the Asia Pacific (APAC) Trajectory Based Operations (TBO) Pathfinder. The prototype will be used as the basis to build the new FF-ICE Release 1 System that CAAS is currently procuring.



Section 3: Bridging to the Future of Asia-Pacific Aviation

Challenges and Opportunities

Asia-Pacific aviation is entering a period of profound change. Traffic growth will coincide with new airspace users, deeper digital dependence, disruptive weather, and geopolitical uncertainty. For Air Navigation Service Providers (ANSP), the challenge will not simply be to manage more aircraft, but to manage a more interconnected and less predictable system.

For Singapore, national performance will increasingly depend on regional performance. Aircraft, weather, data, and disruption move across FIR boundaries. Future air traffic management must therefore place interoperability, shared situational awareness, and coordinated decision-making at its core.

Maximizing Capacity Across the Network

Airports can add terminals and runways, but airspace is becoming the new limiting factor. It must be used more effectively. In Southeast Asia, a weather event, capacity restriction, or rerouting in one FIR can quickly affect several others.

ANSPs must move from reactive traffic management toward collaborative and predictive Air Traffic Flow Management. The objective should be broader than reducing delay in one sector; it should be to maximize safe and predictable network throughput under nominal and off-nominal conditions.

That requires reliable data, meaningful performance measures, better demand/capacity forecasting, and earlier coordination across borders.

Integrating New Users from Surface to Space

Commercial and military aviation will increasingly share the aerospace domain with uncrewed aircraft, advanced air mobility vehicles, and commercial space operations.

In Singapore, UAS may support infrastructure inspection, maritime activities, emergency response, logistics, public safety, and airport services. Their integration will require clear operating concepts, safety cases, trusted data exchange, and coordination among operators, airports, regulators, defense authorities, and ANSPs.

We are at the start of a new space race. Launch and re-entry operations create similar challenges at a different scale. Large airspace closures may become increasingly difficult to sustain as activity grows. More dynamic approaches will be needed to integrate new entrants while preserving access for civil and military users.

Building Secure, Interoperable Digital Systems

Future aviation systems will depend on continuous information exchange among aircraft, ANSPs, airlines, airports, regulators, and meteorological services. Digitalization can improve predictability, but uneven modernization across the region creates integration challenges.

New capabilities must function within networks of legacy and modern systems. Digital twins, modelling, and simulation can help stakeholders test routes, ATFM measures, automation tools, and contingency plans before deployment. Cybersecurity and resilience must be designed into the architecture from the outset.

Preparing for More Disruptive Weather

Weather is likely to become an even greater operational constraint. Asia is already experiencing major impacts from extreme rainfall, flooding, heat, and tropical cyclones, while research indicates that clear-air turbulence may increase in a warming climate.

The issue is not only whether a storm becomes stronger, but how its effects propagate through the network. Convective weather can reduce route availability, lower airport acceptance rates, increase diversions, and create downstream congestion. Turbulence can affect passenger and crew safety, routing, and efficiency.

ANSPs will need impact-based weather intelligence, understanding not only what the weather will be, but what it will do to capacity and operations. Better forecasting, rapid sharing of observations, integrated weather-traffic models, and coordinated recovery plans will be essential.

Enabling the Workforce of the Future

Traffic growth will place pressure on a controller workforce that is already difficult and time-intensive to develop. Meeting future demand will require both expanding workforce capacity and reducing future workforce demand.

On the capacity side, ANSPs must take a full lifecycle view, from recruitment and training through certification and operational readiness. Data-driven workforce planning can help identify future demand, skills gaps, and pipeline constraints, while improving training effectiveness and reducing time to operation deployment.

At the same time, technology and operational design must help reduce demand on the workforce. Automation and decision-support can augment ATC delivery, enabling controllers to shift from continuous tactical intervention toward higher-level monitoring of increasingly automated operations. Workforce considerations should therefore be embedded directly into the vision of the future airspace and system design.

Enabling a More Proactive Safety Paradigm

The anticipated growth and diversification of aviation, such as the integration of new entrants, will also require an evolution in how safety is managed. Existing safety frameworks have delivered exceptional performance, but increasing complexity will require safety management to become even more predictive, data-driven, and adaptive.

A key opportunity is to combine operational data, safety reports, and advanced analytics (e.g., AI/ML) to identify emerging risks and weak signals before they result in incidents. This should complement continuous investment in a strong safety culture and

voluntary reporting systems, ensuring lessons are translated rapidly into operational improvements.

Safety policy and oversight must also evolve alongside new operations. Novel approaches to Beyond Visual Line of Sight operations, separation standards, airspace classification, and risk-based oversight will be necessary to enable growth while maintaining an acceptable level of safety, particularly where conventional aviation intersects with new entrants.

The objective will be to ensure that safety innovation progresses alongside operational innovation rather than following it.

A Future-Ready Role for MITRE

Meeting these challenges requires more than procuring new systems. It requires the ability to identify operational shortfalls, understand their causes, establish meaningful metrics, and test solutions within the wider system.

MITRE brings together aviation-domain expertise, data science, AI/ML, systems engineering, human factors, modelling, and cybersecurity. This can help governments and ANSPs evaluate problems, rapidly prototype solutions, and understand how new capabilities will interact with existing procedures, people, and technologies (Man-Machine-Method).

MITRE's work spans traffic-flow performance, UAS integration, mixed civil-military operations, and operational experimentation. MITRE is also expanding its weather-modelling and global weather-intelligence capabilities through its collaboration with The Weather Company, ESRI, and others.

The aim is not innovation for its own sake, nor the direct transfer of solutions from one system to another. It is to provide independent evidence, realistic experimentation, and locally relevant analysis that help decision-makers move promising new concepts safely into operations.

The region's future aviation system will be shaped by choices being made today. ANSPs that succeed will plan beyond national boundaries, measure performance at the network level, and build resilience into technology and operations. MITRE can contribute by connecting research with implementation and supporting the regional cooperation needed to keep Asia-Pacific aviation safe, efficient, resilient, and orderly.

> Meeting future demand will require regional ANSPs to collaborate across borders, optimize the aviation network as an integrated regional system, and translate research into secure, scalable operational capabilities.
>
> — Christopher Pertsch, MAPS Site Leader

Through our public-private partnerships and U.S. federally funded R&D centers, we work in partnership with industry to tackle challenges to the safety, stability, and well-being of our nation and the world.