



# ICAO

*International Civil Aviation Organization*

**SEVENTH MEETING OF THE ASIA/PACIFIC AIR  
TRAFFIC MANAGEMENT AUTOMATION SYSTEM  
TASK FORCE (ATMAS TF/7)**

*Bangkok, Thailand 2-4 June 2026*

Agenda Item 4: ATM Automation System Implementation Experience by States

4.5. Integration with External Systems

## **END-TO-END SYSTEMS INTEGRATION TESTING TO IMPROVE INTEROPERABILITY**

(Presented by Singapore)

### **SUMMARY**

This paper presents Singapore's plan in conducting end-to-end systems integration testing in the modernization of its Air Navigation Services (ANS) systems. Operating on a System-of-Systems (SoS) approach, a dedicated systems integration facility will facilitate advanced system integration testing techniques, including the use of automated scenario simulation and emulator tools for orchestrated and controlled end-to-end SoS-level integration validation, enabling early issue detection and robust performance assurance beyond traditional pair-wise system validation. The facility may also support cross-border data exchange validation, fostering international collaboration to strengthen global aviation safety and resilience.

## **1. INTRODUCTION**

1.1 At ATMAS TF6 in June 2025, Singapore presented IP/02 to highlight the need for modern architectural design principles in Air Navigation Services (ANS) systems to address the aviation industry's rapid transformation. Traditional closed architectures are no longer sufficient given challenges such as rising air traffic, evolving operational requirements, increasing airspace complexity, climate change, technological advancements and cybersecurity threats.

1.2 To meet these demands, Singapore recommended four guiding principles:

- a. Modularity – enabling flexible system upgrades and scalability.
- b. Open interfaces with common data standards – ensuring interoperability and reducing vendor lock-in.
- c. Security-by-design – embedding resilience against cyber threats.
- d. Continuous innovation – supporting new operational concepts and long-term adaptability.

1.3 Singapore is applying these principles in the modernization of its ANS systems with the aim to achieve better vendor integration, operational flexibility, stronger cybersecurity, and cost efficiency.

1.4 The transformation towards data-driven, information-centric services, however, introduces a new paradigm for integration and testing, requiring more sophisticated validation approaches - existing system-level pair-wise testing setup and methodology may be insufficient to detect interoperability issues early.

1.5 In particular, modern automation systems supporting ATM are no longer restricted to tactical control domains. The need to ensure interoperability with non-tactical systems (e.g., ATFM, AIMS, etc) will require effort to set up a comprehensive testing suite to iron out any issues before deployment for operations.

## **2. DISCUSSION**

2.1 The modernisation of Singapore's ANS systems is on-going with plan to progressively build up its next generation ANS systems capabilities and operate as a System-of-Systems (SoS), comprising a suite of complex and interdependent constituent systems that would interoperate seamlessly to function effectively as a collective whole.

2.2 Given the safety-critical nature of ANS systems, comprehensive SoS-level integration testing is required to validate end-to-end interoperability and ensure robust performance prior to major system deployment.

2.3 Hence, Singapore has identified the need to establish a dedicated systems integration testing facility that is equipped with integrated scenario simulator and emulator testing tools. The tools will include capabilities such as generation and orchestration of nominal and anomalous scenarios and ANS messages that closely align with ANS operational workflows to enable realistic cross-cutting test scenarios. In addition, there will be tools to ensure test results are traceable with evidences and metrics (e.g. message samples, payloads, run logs) to facilitate troubleshooting and analysis of systems integration issues.

2.4 Building on these advanced tools and capabilities, the facility will serve as a platform for system-level pair-wise and SoS integration testing, involving 3 or more systems, to enable early identification of technical and compatibility issues, validation of system interfaces and data exchanges, and analysis of emergent SoS behaviours. The facility is also expected to validate complex SoS capabilities and assess interoperability when new systems are introduced and evaluate performance under simulated operational scenarios.

2.5 Importantly, these testing activities can be conducted in a controlled environment, independent of live systems, hence ensuring minimum disruption to safety-critical live systems.

2.6 To further strengthen interoperability, the systems integration testing facility could be expanded with the capability to involve broader aviation ecosystem, including the opportunities for the conduct of cross-border data exchange validation. This will enable seamless collaboration across different ANS systems and stakeholders, fostering collective improvements in safety and resilience within the global aviation ecosystem.

## **3. ACTION BY THE MEETING**

3.1 The meeting is invited to:

- a) note the information contained in this paper;
- b) share experiences and potential challenges in conducting end-to-end system integration testing; and

- c) discuss any relevant matter as appropriate

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