



## Strengthening Aviation Resilience Against Global Navigation Satellite Systems (GNSS) Interference

Gerard Peacock, Head (Flight Operations), Flight Standards Division, CAAS

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Since the Global Positioning System became fully operational in the mid-1990s, satellite-based navigation has become foundational to modern aviation, providing positioning accuracy for precise and efficient aircraft operations. That capability, however, can no longer be taken for granted. Radio frequency interference (RFI), including jamming and spoofing, has emerged as a significant international aviation safety concern.

Consider a scenario increasingly familiar to flight crews operating in affected regions: an aircraft deviates from its programmed route mid-flight. Its navigation performance

capability degrades. A terrain warning activates, not because of an actual obstacle, but because the navigation system has received false position data. While each of these effects – loss of position updating, degradation of navigation capability and spurious terrain alerts – can generally be managed in isolation, together their effects compound, increasing workload, heightening operational complexity and generating uncertainty for both flight crews and air traffic controllers.

Recognising the growing challenges posed by GNSS interference, CAAS established a

multidisciplinary GNSS RFI Taskforce, bringing together expertise across flight operations, air navigation services and airworthiness. The Taskforce sought to develop a common understanding of the threat and coordinate near-term operational and regulatory mitigations to strengthen resilience ahead of the longer-term deployment of avionics and hardware-based solutions. Its work also drew on whole-of-government capabilities where the response extended beyond aviation.

### Building a Common Operating Picture

The Taskforce recognised from the outset that the effects of GNSS interference could extend across flight operations, air traffic management, communications, spectrum management, enforcement and security. Developing an effective response therefore required, as a first step, a shared understanding of the threat and its potential consequences across interconnected domains.

The Taskforce combined multiple data sources, including pilot reports, air traffic monitoring and insights from third-party analytics, to develop a fuller picture of patterns and trends. Pilot reports indicated losses of GNSS capability during particular arrivals, while air traffic monitoring showed that several aircraft

operating in the same area had experienced similar navigation issues. Although the available data was insufficient to identify specific hotspots, combining these sources laid the foundation for a better understanding of the location, timing and operational impact of the interference.

### Enhancing Operational Resilience

While avionics manufacturers continue to develop longer-term technological solutions, such as more resilient receivers and improved spoofing detection, these innovations will require time to certify and deploy at scale. Operational resilience, however, cannot wait.

The Taskforce therefore focused on operational and procedural mitigations that could strengthen resilience in the near term. These covered preparing flight crews through training and simulator scenarios for GNSS anomalies; maintaining safe operations through fallback and degraded-navigation procedures, aircraft Minimum Equipment List considerations and the continued role of conventional ground-based navigation aids; and coordinating the operational response through pilot-controller procedures and ATC contingency responses, including radar vectoring and other tactical responses.





Collectively, these measures aimed to embed GNSS resilience within normal operating procedures and system planning, rather than treat it as an ad hoc response to an interference event. The Taskforce also worked closely with Singapore air operators to ensure their operational procedures were aligned with up-to-date guidance from the original equipment manufacturers and operational best practices.

Improving Operational Communication and Reporting

GNSS interference also presents communication challenges both during and after an event. In flight, navigation anomalies or false terrain warnings may prompt immediate flight crew responses before air traffic control is aware of the underlying cause. After the event, differences in terminology, reporting formats and data quality can make occurrence information difficult to consolidate and analyse across States.

In the absence of globally standardised phraseology for communicating GNSS interference, the Taskforce examined operational scenarios to develop practical coordination procedures and common terminology. It also considered the appropriate use of Notices to Airmen and Automatic

Terminal Information Service advisories to provide affected airspace users with timely and useful information.

Recognising the need to further harmonise these efforts at the regional and international levels, Singapore also contributed its operational experience to ICAO Asia-Pacific discussions on standardising GNSS interference reporting and coordination, including through its role as Rapporteur of the Procedures for GNSS and Data Link Disruption Ad Hoc Group. The Group drafted an initial guidance framework for common reporting processes, terminology and minimum data requirements. Greater consistency in operational communication and occurrence reporting would allow information from different States to be more readily consolidated into a coherent regional picture, supporting earlier identification of trends, more effective information sharing and better coordination of mitigation measures.

A Whole-of-Government Response

Given the potential for GNSS interference to affect multiple sectors beyond aviation, the Taskforce worked with whole-of-government partners to enhance detection and monitoring capabilities, as well as information sharing across agencies. Spectrum management agencies provided insights into the radio

frequency environment and emerging interference trends, while relevant regulatory and enforcement agencies contributed perspectives on the regulation and control of prohibited devices capable of disrupting GNSS signals.

Together, these efforts complemented aviation’s operational mitigations by improving the ability to detect interference, understand its potential sources and reduce the risk of domestically generated interference affecting aircraft operations. They also brought aviation safety, technical, policy and enforcement considerations together within a more coordinated national response.

The Way Forward

The Taskforce has established important foundations, but further work is needed to strengthen and sustain GNSS resilience. Priorities include implementing and refining operational measures, enhancing detection and monitoring, and regularly assessing the effectiveness of mitigation measures as GNSS RFI evolves.

CAAS will continue to contribute to ICAO Asia-Pacific efforts to ensure harmonised responses across the region. Beyond information sharing, continued collaborations to develop contingency arrangements that support the continued provision of safe and interoperable air navigation services when GNSS is degraded will be important. At the same time, CAAS will track developments in resilient avionics, spoofing detection and alternative navigation capabilities, and consider how emerging solutions should be incorporated into future regulations, operational procedures and infrastructure planning.

As GNSS continues to underpin global aviation, ensuring its resilience will remain a shared responsibility. Technology will form an important part of the solution, but resilience will depend equally on the ability of regulators, operators and international partners to develop a common understanding of emerging threats and respond in a coordinated manner. Through the Taskforce, CAAS has laid the foundation for a more integrated approach, strengthening Singapore’s operational resilience while contributing to the broader international effort to safeguard aviation.

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Editor

Ong Chun Yang

Assistant Editors

Michelle Teo  
Nadine Kang

Contact

CAAS\_Safety\_Promotion@caas.gov.sg  
www.caas.gov.sg

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