*International Civil Aviation Organization*

**THE THIRD MEETING OF THE ASIA/PACIFIC GBAS/SBAS IMPLEMENTATION TASK FORCE (APAC GBAS/SBAS ITF/3)**

*(Video conference, 27-28 September 2021)*

**Agenda Item 3**: Updates from States/Administrations about GBAS/SBAS Implementation

# Concept of Operations for GNSS Event Reporting

(Presented by Civil Aviation Authority of Singapore, prepared by Authors from MITRE Corporation)

**SUMMARY**

This paper highlights potential vulnerabilities to Global Navigation Satellite System (GNSS) disruptions, mitigations, and a resultant Concept of Operations (CONOPS) for the successful mitigation of a GNSS Outage in a State. It makes recommendations on the GNSS Outage Responses and Reporting, based on Air Traffic Control (ATC) and airline operators' feedback.

This paper focuses on detection of the GNSS outage events and a proposed response paradigm that addresses the need for the dissemination of critical information.

Key objectives of this CONOPS paper are to describe:
1. How to identify and declare GNSS events.
2. What information should be collected.
3. How to disseminate information and to whom it should be communicated.

## 1. INTRODUCTION

1.1 Real world Global Navigation Satellite System (GNSS) events are not common in 2020, although a non-trivial number of cases is documented globally each year. The threat is growing due to the wide availability of low-cost equipment and the increased use of GNSS interference measures by the States.

1.2 The GNSS provides extremely accurate position, velocity, and timing for a wide range of users worldwide, most notably, the aviation industry. A whole generation of beneficial operational capabilities has been achieved including Area Navigation (RNAV), surveillance systems such as Automatic Dependent Surveillance-Broadcast (ADS-B), as well as improved ground and collision-warning systems. It should be noted that the satellite signals making up the GNSS are very weak and, consequently, more vulnerable to interference than ground-based signals. While attempts to interfere with the GNSS signal are relatively rare, the potential for significant disruption to operations and consequent damage to the aviation industry's reputation for reliability and safety that would inevitably result should not be dismissed. Experience shows the probability of a GNSS event occurring to be relatively slim but if one occurs, the potential for damage is significant.

1.3 Singapore has assessed its current sensitivity to GNSS events and made recommendations on how aviation stakeholders could mitigate the impacts. A Concept of Operations (CONOPS) outlining how a mature response system could react is presented. The resulting CONOPS provides a clear explanation of how a prepared set of stakeholders could effectively work together through pre-planning and effective communication to minimize the safety and economic impacts of any future GNSS disruption.

## 2. DISCUSSION

### 2.1 GNSS Event Concept of Operations

GNSS outages can result from a variety of actions, some of which are man-made while others are environmental. Most events happen because of jamming or spoofing. A jamming event denies reception of some or all GNSS satellite signals to the aircraft and is identifiable by the crew. A spoofing event involves the GNSS receiver being sent a false GNSS signal.

### 2.2 GNSS Outage Responses

2.2.1 A tracking system is essential to the effective resolution of a GNSS event. This CONOPS assumes a "GNSS event" tracking system exists or will be developed. This system would be considered an Aeronautical Information Service (AIS) that exists as part of the Aeronautical Information Management (AIM) system run by the Air Navigation Service Provider (ANSP). It does not have to be complex, but it does have to be available to all GNSS stakeholders for the purpose of documenting events and ensuring their widest dissemination to relevant parties. Distribution of the GNSS event report information could conceivably occur via the Flight and Flow Information Collaborative Environment (FF-ICE).

2.2.2 Aviation stakeholders include airlines, pilots, air traffic controllers, and maintenance technicians. Other stakeholders exist beyond aviation in other industries that use GNSS as well.

2.2.3 Verified GNSS events should be reported to the NOTAM system, airport Automatic Terminal Information Service (ATIS) broadcasts, PIBs, and other existing methods. However, a more tailored AIS system is needed beyond NOTAMs for a few key reasons:

- There are many "false-alarms" caused by equipment failures and other anomalies that should not be reported via NOTAM and other existing methods. However, this new system would capture each of these events in a report so that valid, systemwide GNSS events can be automatically and rapidly identified and disseminated.

- The need for the spatial and temporal correlation of reports may not fit well into the existing reporting systems.

- Existing aviation systems are not connected to all potential GNSS event stakeholders, but the longer term evolution of systems like FF-ICE envision this type of broad connectivity.

### 2.3 GNSS Event Stakeholder Reports

2.3.1 Given the wide range of potential scenarios for GNSS events and a corresponding range of potential stakeholders in any given event, it is important to centralize the collection of all reported events and the relevant information into a dedicated Automated Data Processing (ADP) tool running at a designated location. The actual location chosen for this "GNSS Event Tracker" is not the overriding issue and could be determined through engagement with GNSS Event stakeholders. The important point is to ensure all relevant stakeholders can provide input and receive output as warranted.

2.3.2 The information collected needs to be recognizable by stakeholders that a GNSS event may be occurring. If the proper information is not collected and centralized, GNSS event reports may be mis-interpreted as simple component failures or human perception errors. A singular report may require a minimum response whereas three or more would indicate a likely GNSS event. In that case, a more involved response would be warranted, including the execution of the GNSS event BCPs.

2.3.3 A key item to successfully identifying a GNSS event is a report that captures the most relevant information and can be entered into the centralized tracking system in a timely way. It recommends that the event report normally be filled out by the stakeholder who is experiencing the GNSS problem, but in cases where this is not possible anyone who has access to a GNSS report can and should provide it. For an aircraft, this means that normally if a pilot is experiencing a GNSS event, the pilot would enter the report into the reporting mechanism via on-board automation tools or through voice with ATC or their company. If ATC experiences a problem, such as loss of ADS-B targets on their radar, the controller would enter an ATC report into the reporting mechanism.

2.3.4 Although the reports can include detailed information, the most relevant information should be the focus of stakeholders filling out reports. The most critical information that should be included by all stakeholders is the ***date and time of the event, the location of the event, and the nature of the operational impacts***. This information provides insight into the geographic area impacted, the effects of the event, and the range of stakeholders that may be experiencing impacts. It is expected that each stakeholder group would have a different reporting form tailored to their needs.

2.3.5 The report examples below could be either electronic or simply transmitted by voice. In the case of the airline, they could notify their operations center using voice comm and have them enter the report into the centralized collection system. For ATC, a voice report could be made by the controller working the affected position and conveyed to their Supervisor who would enter the report. Alternatively, the forms could be hosted in electronic systems for the users. As an example for aircraft that are properly equipped, the form could be electronic and hosted on the pilots Electronic Flight Bag (EFB) or by the certified avionics in a Multi-Purpose Control and Display Unit (MCDU). It is common for EFB and avionics to be integrated to the aircraft sufficiently to allow the proposed report to be automatically completed for the pilot with the relevant information which would reduce pilot workload, potential report errors, and the time for the pilot to send the report. The aircraft report could be sent using existing communications links such as Satellite Communications (SATCOM), Very High Frequency (VHF) data link, High Frequency (HF) data links, or other modes of ground or airborne communications. The information could be sent to the individual airline companies, service providers, or directly to an ANSP and then routed into the appropriate networks for the information to arrive at the centralized reporting tool. ATC and other stakeholder reports could also be designed to leverage available electronics with a goal of simplified data entry and expedited report completion.

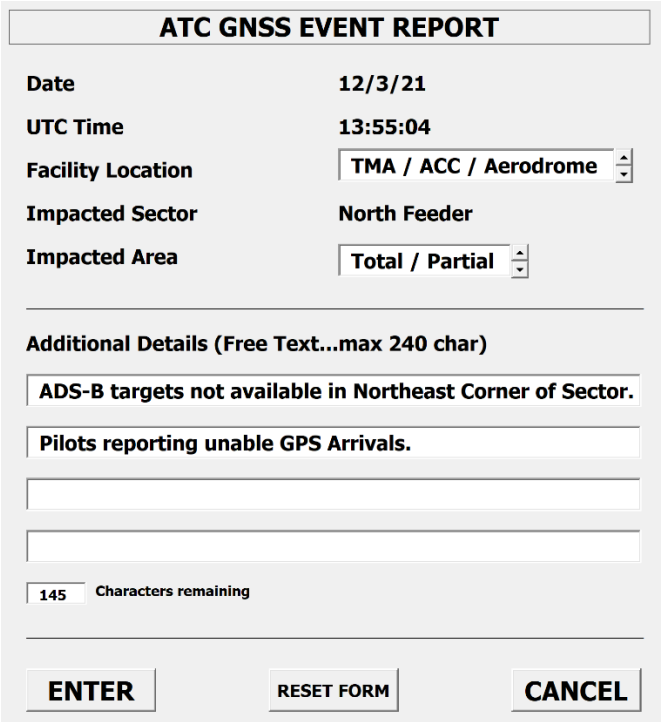


**Figure 2.1 ATC GNSS Event Report**

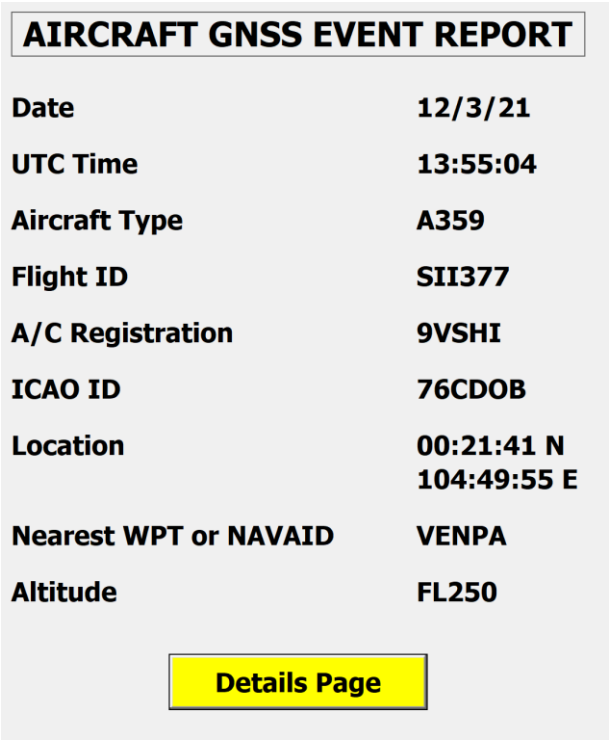


**Figure 2.2 Aircraft GNSS Event Report**

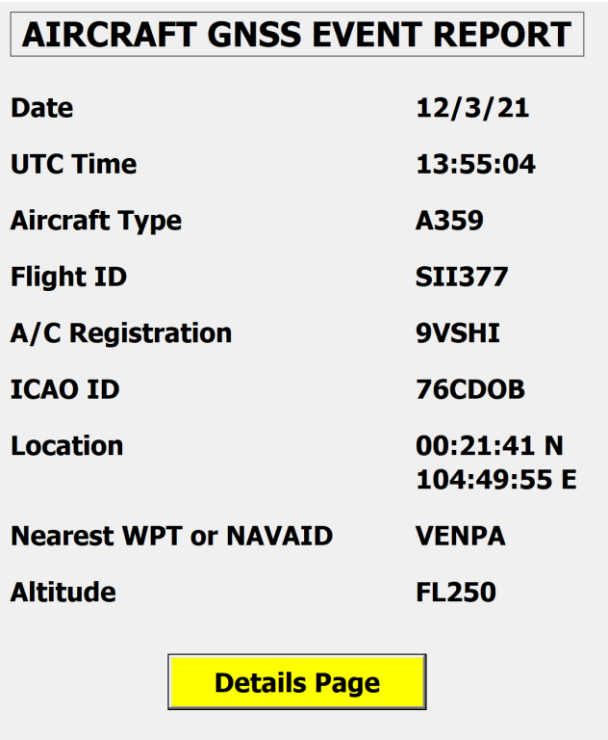


**Figure 2.3 GNSS Event Report Detail**

2.4 First Report

2.4.1 The first report of a GNSS anomaly on an aircraft may be due to an alert from the navigation system. However, this aircraft may have many navigation sensors with reversionary modes for RNAV and RNP, a loss of GNSS may not cause an urgent alert to the crew. In some cases, it may not immediately notify crews of a loss of GNSS at all since the aircraft's RNAV or RNP capability may not be initially impacted and may take several minutes to degrade after loss of GNSS.

2.4.2 The ADS-B Out function relies on GNSS. For many aircraft, a loss of GNSS may first be observed by a transponder warning. Historically, transponders from the 1960s through the 1980s had a mean time between failure of less than 10 years. Modern transponders are far more reliable and are likely to last the life of the aircraft. For system redundancies, aircraft are equipped with at least two units to maximize aircraft operational availability. Putting these two elements together, a pilot reporting that both of his transponders are indicating some sort of failure mode on the same flight should be a clear indication of a likely GNSS interference event. This could be caused by a common mode failure in the two independent units not related to GNSS, but it is more likely to be GNSS signal induced since the transponders have such high reliability.

2.4.3 Because of ADS-B's dependence on GNSS, the States could consider monitoring ADS-B broadcasted data from ground ADS-B stations or via space-based ADS-B reception products. This may allow for the rapid and automatic detection and logging of both poor integrity/accuracy measures from aircraft and/or complete dropouts of ADS-B from aircraft in known coverage. This approach would require some development as there are other reasons for off-nominal ADS-B Out data other than GNSS interference.

2.4.4 Another source of an airline generated first report may be from information received internally from company maintenance, dispatch, or safety personnel. A pilot, for example, may experience an avionics problem that does not impact the operation of the aircraft and,

therefore, does not result in notification to ATC. However, that information would most likely be made available to maintenance personnel. If troubleshooting revealed no evidence of equipment malfunction, a GNSS event may be the culprit, creating the need to generate a first report.

2.4.5 Upon first report or notification of a potential GNSS event, ATC should try to confirm the event and identify potentially impacted aircraft. ATC should query pilots to determine if more than one aircraft is affected, the nature of the impacts to the individual flights, and ATC services that might be needed. Some aircraft avionics equipment sets are more sensitive to interference than others. It is important after a first report to try to ascertain as much information as possible regarding the types of aircraft impacted, specific operators, and impact to the aircraft's operational capabilities. Instances have occurred during GNSS events wherein the issue was related to a particular model of avionics on-board the aircraft. Therefore, a possible GNSS event should not be completely ruled out even if other aircraft report normal operations. ATC should remind crews to file reports, if possible, to ensure the centralized reporting system is properly updated so information can be distributed to all stakeholders. A pilot notification to ATC that they are experiencing a problem or a controller notifying them of an ATC problem does not constitute the filing of a report because other stakeholders would not have the relevant information being passed between ATC and pilots.

## 2.5 **Second Report**

2.5.1 A second report to the GNSS event tracker will automatically generate a "**Warning**" alert to system subscribers if two events occur within a threshold time span. The value of this threshold time span would need to be determined through practice and further study but would likely be between 15 minutes and 6 hours. The threshold time should be long enough to identify events that only affect a limited geographic area or particular avionics model, but not so long as to cause numerous false alarms due to random unrelated equipment issues.

2.5.2 Upon notification of the second report warning, ATC will notify pilots that a GNSS event is suspected and query the status of navigation and other GNSS functions on-board their aircraft. The difference in this case from the first report is that in the single case, ATC is attempting to determine whether pilots are being impacted. In the case of a second report, ATC is warning pilots that a possible event is occurring and any aircraft with even minor impacts should advise ATC. This will either lead to a third report or simply result in continued, heightened vigilance until the warning times out.

2.5.3 Ground personnel should also coordinate with flight crews to ensure clear communications about the details of the situation. This communication may be performed via SATCOM, voice, or Aircraft Communications Addressing and Reporting System (ACARS) but should have positive acknowledgement of receipt information as any of the systems may be compromised during an adverse event. If no acknowledgment is received, Operations personnel should attempt alternate means of communications with flight crews and assume, for the time-being, the initial method of communication is not functional. The loss of that communication system should be included in a report to the GNSS event tracker. In doing so, it may be possible to determine the cause of the event, communicate possible effects to other aircraft, and help reach a resolution.

## 2.6 **Third Report**

2.6.1 Upon receipt of a third event within the time event threshold, the GNSS event tracker will notify stakeholder subscribers that an active GNSS event appears to be in progress. Each stakeholder has a responsibility to follow their predetermined and pre-coordinated mitigation plans for the event.

2.6.2 ATC will make a broadcast announcement on Very High Frequency (VHF) radio that a GNSS event is in progress, NOTAMs will be issued, and ATIS will be updated to reflect the GNSS events and impacts. This announcement will include any known specifics regarding the nature and location of the event. If too many aircraft are calling ATC at once to report a loss of capability and/or need for a new clearance, the VHF voice channel may become congested. In this event, ATC will periodically add to the announcement of the event that aircraft do not need to directly report the event to ATC on the voice channel. ATC will assume all aircraft in the affected area are navigating without GNSS. ATC should consider keeping all capable aircraft on RNAV arrival and departure procedures unless it results in safety of flight, workload, or other issues where radar vectors are a better strategy for managing traffic. For approach, aircraft should be assigned either an ILS or a visual approach depending on the weather conditions and needs of flight crews and ATC. Depending on the nature of the outage and the equipment on-board, some of the aircraft may not be able to maintain RNAV. ATC should expect that some flight crews may request a hold to assess the situation and follow proper procedures to address the event before proceeding. ATC should anticipate that pilots may also request a diversion because of the event either for departing aircraft to return to destination airport or for arriving aircraft to land at an alternate neighbouring airport. Some aircraft may require radar vectors to the ILS or out of the airspace. Many aircraft will likely require a new clearance once the event is in progress and affecting the airspace.

2.6.3 Management of ATC workload is critical. While ATC should be flexible in accommodating air crews' requests, they must also maintain separation and ensure the situation does not become chaotic. Inbound traffic may need to be re-routed before arriving in the affected area if traffic volumes or workload become too excessive to maintain safety. Scheduled flights inbound for destination airport may need to be held on the ground until the safe capacity of the airport can be established and aircraft already airborne are landed safely. Outbound aircraft will likely be delayed until ATC can establish a better understanding of remaining capabilities and operators can ensure proper functions of aircraft systems and compliance with operational regulatory requirements.

2.6.4 As more information becomes available, NOTAMs and ATIS should be updated along with major mitigations in place.

2.6.5 Air carrier air crews and ground-personnel should remain in close contact to relay all information about the event. Each aircraft is the best source of information regarding impacts to the system. This information should flow between the air crews, the company ground personnel, the aircraft manufacturer, and the avionics manufacturer to further understand aircraft impacts and mitigations with a goal toward resuming normal operations.

## 3 GNSS Event Concept of Operations Recommendations

3.1 Develop and implement a centralized GNSS event reporting capability for use by all GNSS event stakeholders within a State.

3.2 With input from stakeholders, develop and implement procedures to identify, communicate, and coordinate responses to a GNSS event.

3.3 Develop a set of specific information that is most critical to be included in a GNSS event report to support identification, mitigation, and forensic analysis.

3.4 Define the roles and responsibilities for each aviation stakeholder and then do the same with all non-aviation stakeholders.

3.5 Engage entities outside of aviation, such as the Land and Maritime Authorities, to understand potential impacts to other industries for a GNSS event and their need to engage in GNSS resiliency planning.

3.6 Use planning meetings, table-top exercises, and/or simulations to develop a set of GNSS event scenarios that can be used to illustrate the implementation of GNSS BCPs.

## 4 ACTION BY THE MEETING

4.1 The meeting is invited to:

a) Note the GNSS Event Report CONOPS proposed by Singapore; and
b) Seek ICAO's further guidance on GNSS Threat Mitigation.