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Twenty Eighth Meeting of the Communications/ Navigation and Surveillance Sub-group (CNS SG/28) of APANPIRG

Bangkok, Thailand, 1 July – 5 July 2024

Agenda Item 6: Navigation

6.2 Review Report of the Sixth Meeting of GBAS/SBAS Implementation Task Force (GBAS/SBAS ITF/6)

REVIEW REPORT OF THE SIXTH MEETING OF ICAO ASIA/PACIFIC GBAS/SBAS IMPLEMENTATION TASK FORCE (GBAS/SBAS ITF/6)

(Presented by the GBAS/SBAS ITF Co-Chairs)

SUMMARY

This paper provides information on the outcomes of the GBAS/SBAS ITF/6 held in Bangkok from 7-9 May 2024 for the review by the meeting.

1. INTRODUCTION

1.1 The Sixth Meeting of the ICAO Asia/Pacific GBAS/SBAS Implementation Task Force (GBAS/SBAS ITF/6) was held in Bangkok on 7-9 May 2024. A total of 59 participants from States, Administrations, IFALPA and ICAO were registered for the GBAS/SBAS ITF/6. A total of eight (8) Information Papers (IPs) and seven (7) Working Papers (WPs) were presented in the meeting. The relevant presentations and documents are available at following link: icao.int/APAC/Meetings/Pages/2024-GBAS-SBAS-ITF6.aspx.

2. DISCUSSION

2.1 The meeting deliberated on the following main Agenda Items:

Agenda Item 2: Progress on the work of Expert Group constituted to:

- Draft Guidance Document on Implementation Process for GBAS & SBAS.

Agenda Item 3: Updates on GBAS-SBAS & States's Implementation status

Agenda Item 4: GNSS Interference and its impact to GBAS & SBAS

Agenda Item 5: Review of Action Item List

2.2 Progress on the work of Expert Groups

2.2.1 Updates on Draft Decisions of GBAS-SBAS ITF-5 -Secretariat

The Secretariat recapped the draft Conclusions taken in GBAS-SBAS ITF 5 and informed the meeting that the GBAS-SBAS ITF had been extended for another three-year term (up to 2026) by CNS SG/27 through Conclusion CNS SG/27/08 to complete the following remaining tasks for fulfilling the objectives stated in the Terms of Reference (ToRs) of the APAC GBAS/SBAS ITF:

- GBAS and SBAS implementation guidance documents.
- Workshop/Meeting for APAC airspace users and regulators; and
- Discussion and deliberation on technical issues in relation to GBAS/SBAS Safety Assessment and Performance Demonstration.

2.2.2 Expert group 3-2 – Guidance Document on Implementation Process for GBAS (Co-chair)

Mr. George Wong, Co-Chair of the task force, presented the progress of Expert Group 3-2 in developing the guidance document for the implementation of GBAS. The first draft of guidance document for implementation of GBAS was presented in APAC GBAS/SBAS ITF/5 for seeking/collecting comments from States/Administration on the draft guidance document. Taking reference to those comments raised in APAC GBAS/SBAS ITF/5, multiple rounds of review were conducted through web-meeting and circulation by emails, involving Expert Group members and delegates of States/Administration, for discussion on those consolidated comments/proposed amendments after APAC GBAS/SBAS ITF/5. The revised version draft guidance document for GBAS Implementation after rounds of review was presented in the meeting for final review and endorsement by the Task Force Meeting and onward referral to seek approval by CNS SG.

After thorough discussion on each paragraph of the draft guidance document, a draft conclusion was proposed for members' discussion and agreement for seeking further endorsement by CNS SG on the draft guidance document for implementation of GBAS in the Asia/Pacific Region:

<table>
<tr><td colspan="2">Draft Conclusion GBAS-SBAS ITF 06/01 -</td><td colspan="2">Draft Guidance Document for Implementation of GBAS in the Asia/Pacific Region (placed as Attachment A)</td></tr>
<tr><td colspan="3">What: the draft guidance document for implementation of GBAS in the Asia/Pacific Region developed by the APAC GBAS/SBAS ITF and provided in Attachment A of the Working Paper 02 (WP 02) is ready for endorsement by CNS SG</td><td>Expected impact:
☐ Political / Global
☐ Inter-regional
☐ Economic
☐ Environmental
☒ Ops/Technical</td></tr>
<tr><td colspan="2">Why: To provide guidance to States for the implementation of GBAS</td><td colspan="2">Follow-up: ☐Required from States</td></tr>
<tr><td colspan="2">When: 9th May 2024</td><td colspan="2">Status: Draft to be adopted by APANPIRG</td></tr>
<tr><td colspan="4">Who: ☒CNS Sub group ☐APAC States ☒ICAO APAC RO ☐ICAO HQ ☐Other:</td></tr>
</table>

2.2.3 Expert group 3-1 – Guidance Document on Implementation Process for SBAS (Co-chair)

Mr. Susumu Saito, Co-Chair of the task force, presented the points of discussion on the SBAS implementation guidance document. Since the Fifth Meeting of the Task Force (GBAS/SBAS ITF/5) held in June 2023, the draft guidance document on SBAS has been uploaded to the ICAO SharePoint for review and modification by the Expert Group members. The Expert Group also met online three times (11 September, 17 October, and 5 December 2023) to discuss proposed modifications and address comments raised. However, the Expert Group could not finish considering and addressing all the modifications and comments. The draft SBAS implementation guidance document has not been matured yet, and still needs further revision. Specific points for further discussion and consolidation were presented and deliberated in the meeting. The meeting discussed the way forward to revise and finalize the guidance document with the proposed timeline presented. States/Administrations were also urged to contribute to the guidance document development through the Expert Group. The meeting agreed to work as per the proposed timeline so as to have the first draft presented in the GBAS-SBAS ITF/7 meeting for onward referral to seek CNS SG's endorsement.

2.3 Agenda Item 3: Updates on GBAS/SBAS and States' Implementation status

2.3.1 GBAS status update and further operational experiences (Australia)

Australia briefed the meeting on Australia's GBAS status, information on in-service observations and an update on the number of GLS capable aircraft operating in Australian airports. The meeting was informed that Australia continued to experience incidences of a reduction in GLS Service Availability due to the prevailing Global Positioning System (GPS) satellite constellation in combination with the use of Ionosphere Threat Model, and incidences of lightning induced damage to the GBAS equipment. Australia increased the Routine Flight Inspection interval for the GBAS from 12 months to 60 months. Since the introduction of the new interval, there has been no observable effect on GBAS performance.

2.3.2 SouthPAN status update (Australia)

Australia presented a summary of the SouthPAN program, which will provide a SBAS aeronautical radio navigation service to Australia and New Zealand by 2028 to support en-route, terminal, NPA, and APV flight operations across Australia and New Zealand. The service is currently broadcasting Early Open Services on the L1 and L5 navigation signals. A preliminary probabilistic analysis has identified potential challenges in meeting the ICAO Annex 10, Volume 1 Continuity of Service navigation performance requirements for specific types of approaches with vertical guidance enabled by SouthPAN. Australia is currently exploring available options to notify pilots of predicted periods when specific types of SBAS enabled approaches may be unavailable.

2.3.3 GBAS Status Update in Japan (Japan)

Japan presented the status of GBAS implementation in Japan. Japan Civil Aviation Bureau (JCAB) installed the first GBAS at Tokyo international airport (HND) and is conducting CAT-I trial operation. The goal of the trial operation will be achieved shortly. The Electronic Navigation Research Institute (ENRI) has contributed to the improvement of GAST-D performance in low latitude regions. Currently, ENRI is engaged in research and development activities related to GBAS, including the development of the DFMC GBAS concept and advanced operations with GBAS.

2.3.4 MSAS Program Update (Japan)

Japan informed the meeting that the MSAS was declared operational in 2007 up to NPA due to ionospheric effect. Commercial flight-based trial operations of RNP approach procedures with LPV250 minima was ongoing within limited time at seventeen airports in Japan. The trial operations contributed to an increase in opportunities for landing at local airport and reduced CO2 emission. The feedback from the operators was to identify the need for improvement of system performance. The Research and development activities on Dual Frequency Multi constellation MSAS (DFMC MSAS), including message authentication using L5 QPSK signals, were undergoing at the Electronic Navigation Research Institute (ENRI).

2.3.5 KOREAN SBAS (KASS) AIP and Operation (Republic of Korea)

The meeting was informed that the Republic of Korea completed the Development and Implementation of Korean SBAS (KASS, Korea Augmentation Satellite System). KASS system comprises of seven KASS Reference Stations (KRSs), two KASS Processing Stations (KPSs), two KASS Control Stations (KCSs) and three KASS Uplink Stations (KUSs at 2 sites). KASS is augmenting the GPS L1 signal and providing the APV-I approach services at first in the Incheon FIR. KANSC has been analyzing the KASS signal performance of SIS (Signal in Space) since the APV-I class SoL service was first broadcasted on 28 December 2023. Long-term data accumulation is required. For the accuracy of the KASS system (March 2024), the horizontal accuracy is within 1.2~1.7m and the vertical accuracy is within 2.2~2.7m. KASS is certified by MOLIT with support from experts in certification, safety, and software domain.

2.3.6 GBAS IMPLEMENTATION STATUS IN MALAYSIA (Malaysia)

Malaysia informed the meeting that Ground-Based Augmentation System (GBAS) had been installed in Kuala Lumpur International Airport (KLIA) to support PBN approach procedures CAT 1 for all runways in KLIA. Based on the ionospheric analysis, it was recommended to schedule Kuala Lumpur GBAS operations between 10 pm and 6 pm. GBAS flight inspection and commissioning were carried out in November 2019.

2.3.7 Report of GBAS Proof-Of-Concept Project at Suvarnabhumi International Airport (Japan and Thailand)

The summary of the GBAS Proof-Of-Concept (PoC) Project between Japan and Thailand was presented in the meeting. The project successfully demonstrated that the GBAS equipment operated within ICAO standards using Thailand’s Ionospheric Threat Model developed from local data collection. Throughout the project, issues regarding scintillation and RF interference occurred. While changing the antenna addressed scintillation issues, further work is required to mitigate the RF interference. The GBAS PoC Project successfully demonstrated that GBAS operating in low geomagnetic latitude area affected by the ionospheric irregularities complied to ICAO standards. In achieving operation within the standards, local data should be collected and used to develop an ionospheric threat model that could signify the local ionosphere of the area of operations. This helps giving a more accurate bound (less conservative) of actual occurrences of the effects of the ionosphere thus providing a better performance of the installed GBAS system.

2.3.8 GBAS Siting Considerations at Changi Airport (Singapore)

Singapore aims to install GBAS at Changi Airport to enhance approach and landing flexibility. Singapore shared some GBAS Siting considerations which focused on multiple VDB coverage simulations, based on the antenna heights and locations, so to ensure continuous operations with minimum disruptions due to complex airport environment:

a) Multiple VDBs may increase redundancy of the GBAS coverage for different runway ends.
b) The increased VDB antenna height will improve service coverage for CAT I GLS operations.

2.4 Agenda Item 4: GNSS Interference and its impact to GBAS & SBAS

2.4.1 ICAO Recommendations and Guidance on GNSS Vulnerability (Secretariat)

The Secretariat presented an overview of ICAO's Recommendations and Guidance on Global Navigation Satellite System (GNSS) vulnerability, including the following:

a) Recommendation 6/2 of 11th Air Navigation Conference
b) Electronic Bulletin, EB 2011/56 on Interference to GNSS Signals
c) Recommendation 6/8 of 12th Air Navigation Conference
d) Memorandum of Cooperation with the International Telecommunication Union (ITU)
e) ICAO NSP Liaison Statements to RTCA and EUROCAE on Increased Protection of GNSS Receivers
f) Guidance on GNSS vulnerability & mitigation provided in GNSS Manual (DOC 9849)
g) 40th Session of the Assembly / State Letter 2020/89 / ITU Circular Letter 488
h) ICAO APAC Office issued State Letter T 8/5.10 : AP099/22 (CNS) dated 21 July 2022
i) Appendix C to Assembly Resolution 41-8
j) Resolution on prevention and mitigation of harmful interference to GNSS (Resolution COM 5/5 (WRC-2023)
k) APANPIRG Conclusion 8/43 - GNSS Frequency Based Interference (1997), Conclusion 9/32 - GNSS Frequency Protection (1998), Conclusion 22/28 - Protection of aviation utility of GNSS (2011), Conclusion APANPIRG/27/36: Protection of GNSS signal against jamming (2016).
l) Forms for GNSS Interference Reporting in APAC

2.4.2 Experience with the effect of GNSS Radio Frequency Interference to GBAS operations in Australia (Australia)

Australia shared experience on Global Navigation Satellite System (GNSS) Radio Frequency Interference (RFI) events observed in Australia, their impacts to the Ground Based Augmentation System (GBAS) and measures in place in Australia to mitigate the effect of GNSS interference to GBAS Landing System (GLS) operations. Since the deployment of GBAS, there has only been one instance for the GBAS ground station stopped broadcasting pseudo-range corrections due to GNSS RFI. This resulted in a momentary loss of GLS service. A summary of measures in place in Australia to mitigate against GNSS interference is given below:

a) The GBAS siting process assesses the likelihood of interference from the environment that may impact Reference Receiver performance. This will include the collection of GPS data at candidate sites to identify any potential interference sources.
b) The GBAS ground station Reference Receivers are sited as far as practicable away from public roadways to minimize the likelihood of interference from any Personal Privacy Devices.
c) Prior to the introduction of GBAS at a site, aircraft ADS-B FOM PA data is analyzed to identify any potential interference along approach paths that will be supported by the GBAS.

d) Australia has a robust regulatory framework in place to protect the Aeronautical Radio Navigation Service band. All devices operating within this band must be appropriately licensed by the Australian spectrum management authority. Furthermore, Personal Privacy Devices (e.g. jammers) are prohibited in Australia; and
e) The Australian spectrum management authority conducts awareness campaigns.

2.4.3 GNSS RFI monitoring service by JCAB in Japan (Japan)

Japan Civil Aviation Bureau (JCAB) established the Network Performance Assessment Center (NPAC) in 2020 for the mission of centrally monitoring, analyzing, and assessing service levels of CNS as the core of CNS performance management. The performance monitoring of GNSS conducted by NPAC was introduced in the meeting. NPAC collected GNSS signals by GPM system and provided the following three services to users.

a) GNSS Performance Prediction Service providing availability forecasts for ABAS and SBAS
b) GNSS Performance Monitoring Service providing information on the impact on operations utilizing GNSS
c) GNSS Performance Analysis and Evaluation Service conducting analysis and evaluation of GNSS performance for safe and continuous utilization of GNSS

2.5 Agenda Item 5: Review of the Action list

2.5.1 The Action List of the task force is a collection of technical matters identified during the first meeting of the task force. It provides description, relevance, ownership, and priority to be assessed in each meeting. A review of the status of tasks in the Action List was conducted in the meeting and the follow-up actions, as well as revised target dates, of outstanding tasks were discussed and deliberated in the meeting. Some of the action items had been closed as those actions had been completed and new target dates had been assigned for the remaining ones per the discussion among members in the meeting. The updated Action list as concluded in the meeting is attached as Appendix C in the draft report of GBAS-SBAS ITF/6 as placed in the meeting webpage.

2.5.2 As per the latest status in the updated Action List, the following tasks in high priority are still outstanding:

a) Organize a workshop with airspace users of APAC Region
b) Organize a specific meeting with APAC regulators interested in GBAS/SBAS
c) GBAS and SBAS Safety Assessment
d) GBAS/SBAS Performance Demonstration
e) Develop SBAS Implementation Guidance Document

After deliberation, the meeting considered these remaining tasks essential for fulfilling the objectives of the Terms of Reference (TORs) of the Asia/Pacific GBAS/SBAS Implementation Task Force (APAC GBAS/SBAS ITF).

2.6 Agenda Item 6: Any Other Business

2.6.1 Current Status of GBAS-SBAS Discussion in Navigation Systems Panel (Co-Chair)

Mr. Susumu Saito, Co-Chair of the task force, presented the status of discussion in the ICAO Navigation Systems Panel on GBAS and SBAS including standards for DFMC GBAS and its advantages, such as deemed to be able to provide availability even under severe ionospheric conditions. The meeting was also informed about the following highlights:

a) The GBAS Working Group is developing a baseline airborne MOPS and a baseline development DFMC GBAS would be delivered by Q4 2024.
b) To support deployment of existing GBAS (GAST C and D), updates and maintenance of existing ICAO standards, guidance materials, and manuals, Doc8071 Vol. II are being updated and will further be discussed in the NSP JWGs/12 meeting.
c) GWG will work on creating a GBAS manual.
d) A mature version of the SBAS authentication concept of operations document is planned to be delivered by November 2024.

3. ACTION BY THE MEETING

3.1 The meeting is invited to:

a) Review the Summary Report on the outcome of the GBAS/SBAS ITF/6 Meeting;

b) Adopt the draft conclusion stated in Para. 2.2.2 for endorsement by APANPIRG; and

c) Discuss any relevant matters as appropriate.

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INTERNATIONAL CIVIL AVIATION ORGANIZATION

ASIA AND PACIFIC OFFICE

Guidance Document for Implementation of GBAS in the Asia /Pacific Region

Edition 1.0 – XX 202X
Adopted by APANPIRG/XX

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Records of amendments

Amendment Number	Date	Amended by	Comments

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Appendix 1 – Terminologies and Definition

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1. OBJECTIVES AND SCOPE OF THE GUIDANCE DOCUMENT

The objectives and scope of this document are to provide guidance for the implementation of a Ground Based Augmentation System (GBAS) to facilitate precision approaches.

2. EXECUTIVE SUMMARY

In all weather conditions, vertical and lateral guidance to support an approach provides for an additional level of safety for the activity. Both GBAS and ILS can provide such guidance for precision approaches, and with the ICAO plan to transition to GNSS, GBAS will eventually be the preferred navigation aid to facilitate precision approaches.

In this document, elements for GBAS implementation, as well as roles and responsibilities of stakeholders and performance indicators, are covered with details. The guidance for GBAS implementation is deliberated in 17 different aspects as given in Section 5. Post-implementation activities are also incorporated. States' experiences on GBAS implementation are included in Appendix 3.

3. ROLES AND RESPONSBILITIES OF STAKEHOLDERS

Stakeholders are responsible to provide a safe service with optimal community benefit. Relevant information about roles of ANS providers and regulators can be reference to Appendix B of ICAO Doc 9849 GNSS Manual.

4. PERFORMANCE INDICATORS

Performance indicators are quantifiable indicators based on measurements/statistics to show the performance or progress towards the intended result(s). Each state should consider to establish a set of performance indicators against which the performance of GBAS is evaluated. Examples of performance indicators established by states in the region include:

- Operational Availability of the GBAS
- Reliability (Mean Time Between Outage) of the GBAS
- Mean Time To Repair
- Number of GBAS approaches performed into the aerodrome
- Operation and Maintenance costs
- Status of GBAS based navigation services
- Enhancement in airport capacity
- Fuel saving and environmental performance
- Optimization of ATC procedures and reduction of workload

Since performance indicators are associated with the evaluation on the performance or progress towards the intended result(s), each State may focus on different aspects with benefits from GBAS to serve their own purpose and set up their own set of performance indicators against the performance of GBAS for evaluation under post-implementation review.

5. IMPLEMENTATION PROCESS FOR GBAS

a. Overview

This document is intended to provide **guidance to States** for implementing GBAS, certifying a GBAS installation and approving GBAS service within the APAC region. The material contained in this document is based on the experience of States in the APAC region, ICAO documentation, and other publicly available material.

The GBAS is a Global Navigation Satellite System (GNSS) based air navigation system, intended to support all types of approach, landing, guided take-off, departure and surface operations and may support en-route and terminal operations, consisting of the ground based hardware and software that augments core satellite constellation signals. The system uses the concept of differential corrections to augment the satellite constellation signal in order to provide the required integrity, continuity, accuracy, and availability to support precision approaches up to Category III.

The GBAS consists of three segments:

- **Space Segment**. The space segment consists of the GNSS core constellations which provides position and time information worldwide, using precise range measurements from satellites. Both GBAS ground facility and airborne equipment get their positions and time from the GNSS core constellation.
- **Ground Segment**. The ground segment consists of GBAS ground facility/station, including reference receivers with their antennas installed at precisely surveyed points. The receivers receive GNSS signals to measure distances to each GNSS satellite and send information generated in the receiver to a processor that computes the corrections for each navigation satellite in view and broadcasts via a Very High Frequency (VHF) Data Broadcast (VDB). The VDB messages include (but not limited to):
  - differential corrections to remove the range measurement errors that are common to the ground and aircraft sub-systems (Message Type 1/11);
  - GBAS ground facility specific data, including the integrity parameters to monitor and bound GBAS service integrity risk (Message Type 2); and
  - path points which define the Final Approach Segment (Message Type 4).
- **Airborne Segment.** The airborne segment consists of GBAS receiver on the aircraft that receives information broadcast by the ground station and also receives GNSS signals to measure distances to each GNSS satellite. It then applies the differential corrections on the information received directly from the navigation satellites to obtain a position estimate with the required accuracy. The differentially corrected position is used, along with path-point data, to supply deviation signals to aircraft systems supporting precision approach and landing operations. In addition, the aircraft uses integrity parameters broadcast by the GBAS ground facility to perform integrity checks with protection levels on the aircraft's corrected position estimate.

b. Frame, Phases and Elements of GBAS Implementation Process

Relevant information can be reference to Chapter 7 of ICAO Doc 9849 GNSS Manual.

i. Operational Need Analysis

When considering whether to implement a GBAS, it is important to consider how the GBAS will be used within the existing Air Traffic Management (ATM) environment and the benefits that it will deliver to the State. This should be one of the first steps when deciding whether to install a GBAS. The analysis should involve a thorough examination of:

- current approach capability at the airport including objectives, measures of effectiveness, operational policies and constraints, current capability description, modes of operation, and the existing support environment;

- the reasons for changing or supplementing the existing approach capability at the airport with a GBAS;
- concepts for the proposed GBAS capability including objectives, measurements of effectiveness, operational policies and constraints, proposed capability description, proposed modes of operation, integration issues within the existing ATM environment, stakeholders and personnel interfaces and operational use cases;
- a high level of examination of the potential operational, safety and organisational impacts associated with implementing a GBAS; and
- a summary of the expected improvements, disadvantages and limitations of implementing a GBAS, and alternative technologies.

The following provides examples of key considerations when performing the analysis:

- how the GBAS procedures will be designed, including whether the procedures intend to overlay existing approach procedures (ILS or RNAV look alike) into the airport or are new procedures in their entirety;
- how the implementation of a GBAS aligns with the overarching Navigation strategy for the state;
- industry desire for a GBAS installation;
- whether the GBAS is intended to support autoland and guided takeoffs;
- what level of performance/service the GBAS should achieve;
- the impact of implementing a GBAS on existing ATC procedures associated with instrument approach operations including any changes to pilot interactions, phraseology, and documentation;
- how the GBAS is intended to be used within the operational environment;
- the different modes of operation for the GBAS;
- what level of GBAS status monitoring should be provided to both ATC and maintenance centres;
- what the envisaged technical support environment could look like including responsibility for maintenance and engineering support;
- different operational uses and expected responses under each use case;
- the effect on staff with implementing a GBAS and any new capabilities that may need to be developed;
- what additional training is required for staff to support the implementation of a GBAS capability;
- the limitations associated with implementing a GBAS within the State including aircraft equipage rates, technology evolution, ionospheric environment, site consideration, and support capability; and
- alternative technologies available to deliver the desired capability.

Concept of Operations (CONOPS) and operational needs are interrelated. The analysis should take into consideration of the current CONOPS, as well as any potential supplement/amendment in CONOPS to be developed in the future. Guidance on the development of CONOPS is given in Section 5(b)(v) of this guidance document.

ii. Cost Benefit Assessment

In parallel with the development of the Concept of Operations, a cost benefit assessment should be performed for understanding and determining the viability (i.e. whether it is cost effective) to install a GBAS. The cost benefit assessment should consider:

- life-cycle costs associated with GBAS implementation including acquisition, operation, maintenance, and disposal costs;
- whole of industry costs including costs associated with upgrading aerodrome infrastructure, integration in existing ATM environment, staff training and equipping aircraft with the capability;
- identification of key benefits to be derived from the technology and translation into direct economic costs/benefits, such as an increase in traffic flow rates as aircraft may no longer need to be held outside of critical and sensitive areas of an ILS;
- sensitivity analysis which takes into account the effect of uncertainty on key parameters and the overall effect on the Business Case. A key uncertainty specifically for GBAS is forward equipage rates of aircraft which would directly impact usability of the technology;
- clear articulation of the assumptions used in the cost and benefits assessment and how these impact the Business Case; and
- identification of community benefits, such as reduction in emission and aviation related noise.

The following points identify key benefits envisaged from the implementation of a GBAS:

- One GBAS ground facility may support precision approaches for multiple runways at an airport to improve airport safety, access, and utilisation.
- GBAS can support multiple, variable approach paths to the same runway end to enhance airport capacity and environmental performance with the support of complementary ATC procedures and decision support tools.
- GBAS ground facility does not have critical and sensitive areas and can increase runway throughput compared to the equivalent category of ILS if more aircraft are GLS equipped.
- ILS localiser and glide path antenna arrays are placed adjacent to the runway. In contrast, GBAS requires no equipment to be located within close proximity to the runway strip area, thereby reducing the risk of aircraft and localiser damage in overrun situations or aircraft and glide path damage due to runway excursions.
- GBAS can reduce risk of controlled flight into terrain (CFIT), flight delays or diversions at airports which cannot install ILS on all runway ends because of terrain or other challenges.
- GBAS could reduce system support and maintenance cost in the long term, including simpler, less frequent flight inspections, compared to ILS.
- GBAS could provide stable and consistent approach with no vertical guidance fluctuations.
- Regarding RNP to xLS procedures, the RNP to GLS has a shorter distance from the RF leg to the final approach fix (FAF) than the RNP to ILS.
- With RNP to GLS in getting a shorter distance from the RF leg to the final approach fix under GBAS operations, the benefit of fuel savings would be anticipated.

- GBAS can permit the use of guided curved approach both with lateral and vertical guidance.
- GBAS can support multiple thresholds on the same runway.
- GBAS can support to reduce the approach minima for flight operation on runways with terrain constraints, such as runway with offset ILS.
- GBAS can support several approach glide angles to the same runway and it could allow setting approaches at different glide angles to best fit different kind of aircraft landing at the airport.
- The same GBAS station could serve multiple runways at the same airport and even in different airports if they are within the coverage of the VDB transmitted signal and integrity range. Consequently, number of radio frequencies used at the same airport could be less.
- GBAS can provide guided missed approach functionality, thereby increasing the safety of missed approaches.
- More precise navigation services offered by GBAS in the terminal area may provide an opportunity to greatly reduce the impact of aviation related noise by restricting aircraft to defined three dimensional routes designed to reduce the noise effects. Hence, the current costs associated with noise mitigation and noise abatement may be reduced.

The outcomes of the analysis may be documented in a Business Case that clearly articulates the costs associated with implementation and ongoing operation, along with the envisaged benefits of the technology to the State.

iii. Technical Feasibility Assessment

As part of the planning process, it is important to consider whether a GBAS installation is technically feasible at the specific airport.

The technical feasibility assessment should involve:

- a desktop analysis against siting considerations to identify suitable locations where a GBAS could be installed;
- an ionosphere threat assessment to quantify the effect of local ionospheric conditions on GBAS Integrity and Availability and whether local ionospheric conditions support the installation of a GBAS;
- a VDB coverage assessment to assess the impact of existing obstacles and terrain of VDB coverage;
- a satellite performance assessment to assess satellite signal reception, multipath and interference;
- a tropospheric threat assessment to assess the effects of the local tropospheric conditions on GBAS integrity and availability, and whether local tropospheric conditions support the installation of GBAS; and
- an airborne equipment assessment to assess whether the airborne equipment under the relevant airline fleets supports the application of GBAS.

The following provides guidance on performing each of the areas identified in the technical feasibility assessment:

- **Siting considerations**. The installation of a GBAS ground subsystem involves special considerations in choosing prospective sites for the reference receiver antennas and the VDB antenna(s). The following should be considered as part of the siting analysis:
  - proximity to existing power and communications cabling in the area;
  - soil stability and height of the surrounding terrain and the potential impact on GBAS performance;
  - proximity to aircraft movement areas and the potential impact of aircraft and vehicle movements on GBAS performance;
  - site accessibility for equipment maintenance team and security of GBAS ground facility;
  - proximity to existing infrastructure on and in the vicinity of the aerodrome and their potential impacts on GBAS performance including GNSS signal reception, multipath, and VHF Data Broadcast transmission;
  - regarding multipath to the GNSS reference stations, it is necessary to assess arrangement of them so as not to be affected by the common mode errors;
  - the location of environmental sensitive areas (e.g. critical wildlife habitat, wetlands, contaminated soil);
  - future developments on the aerodrome and their potential impact on GBAS performance and location;
  - potential infringements of the Airport Height Restriction Surfaces surrounding the airport;
  - the location of the VDB antenna should ideally maintain visual line of sight to the Decision Height, Runway Thresholds and along the runway (if the GBAS is intended to support autoland and guided takeoffs); and
  - the likelihood of intentional or unintentional Radio Frequency Interference impacting GNSS signal reception.
- **Satellite Performance**. A satellite signal performance assessment should be performed at each site identified for installation of GBAS ground facility as part of the technical feasibility analysis to quantify:
  - satellite signal reception at each location;
  - the extent of satellite multipath and noise at the location; and
  - the extent of radio frequency interference in the environment and potential impact on satellite signal reception.

  This could involve the short-term deployment of a dual frequency satellite receiver, antenna, and data collection device.

- **Ionosphere**. There are two effects of the ionosphere on GBAS, which are the ionospheric delay and scintillation. Resulted characteristics and severity of both impacts are different in locations (especially in the magnetic latitude) and seasons. It is also known that they change depending on the solar activity, which has an approximately 11-year cycle.

  - Although user's range error component of the ionospheric delay is almost removed under nominal condition using the GBAS correction messages, it could increase if there is a large spatial gradient between the GBAS ground subsystem and the user.
  - The ionospheric scintillation effect on ranging signals, which is frequent loss of lock, is caused by ionospheric irregularities with ionospheric disturbances. It could result lower availability of the GBAS performances.

In the GBAS safety assessment, “nominal” and “anomalous” ionosphere conditions should be defined together with system architecture and safety design of GBAS ground subsystem. Under the former nominal condition, user is protected by the GBAS differential correction messages with an integrity parameter for ionospheric error. In contrast, user is not bounded by the parameter under the latter anomalous condition. Therefore, it is necessary to detect and exclude such erroneous ranging sources with appropriate integrity monitors at the GBAS ground subsystem. Note that the targeted horizontal scale of the disturbances is within a few tens of kilometres.

- Concerning the nominal condition, the Equatorial anomaly is a dominant factor to determine background spatial gradient of the ionospheric delay in the low magnetic latitude region. It has seasonal variation and dependency on the solar activity. Therefore, the vertical ionospheric gradient σ_{vig}, which is an integrity parameter included in the GBAS messages to calculate the user’s protection levels, should be determined, considering these characteristics based on sufficient period of observational data.
- As an example of the ionospheric anomalous condition, plasma bubble which is disturbance with ionospheric density depletion produces steep ionospheric spatial gradients and scintillation on GNSS signals. It frequently occurs after sunset in high solar activity periods. For the safety system design of the GBAS ground subsystem, it is necessary to define ionospheric threat model which describes the ranges to assess the ionospheric effects on the GBAS. Regarding the range definition, underestimation exposes users to unsafe condition whereas overestimation significantly degrades system availability. Detailed assessment is described in another guidance document of GBAS/SBAS safety assessment guidance related to anomalous ionospheric conditions.

- **Troposphere.** Tropospheric delay is another crucial error source for GBAS, where high-integrity positioning is required. The tropospheric delay is usually divided into hydrostatic and wet delay, which accounts for about 90% and 10% respectively. However, the tropospheric delay model is considered as a whole model rather than a hydrostatic and wet separation model in GBAS. The tropospheric delay is a function of the air pressure, temperature and humidity that varies depending on time and location.
  - As the air pressure decreases rapidly by height, the tropospheric delay decreases by height. It is corrected by an exponential function of the height differences between the aircraft and GBAS ground station with parameters broadcast in the Message Type 2 which should be determined by the GBAS provider based on local meteorological data or empirical models.
  - Horizontal decorrelation of the tropospheric delay is assumed to be negligible in the local area of interest for GBAS. When the horizontal decorrelation is not considered negligible, the effect can be bounded by adding tropospheric decorrelation sigma to the uncertainty in the nominal ionospheric delay.
- **VDB coverage assessment**. The ICAO Annex 10, Volume 1, Standards and Recommended Practices stipulate to minimum Approach Service Volume. As part of the technical feasibility assessment a theoretical coverage analysis should be performed to determine the likelihood that VDB coverage requirements will be met. The coverage can be performed using commercially available radio coverage modelling software.
- **Airborne Equipment.** The ICAO Annex 10, Volume 1, Standards and Recommended Practices states the airborne equipment requirements to support GBAS. In addition, RTCA

DO-246() and DO-253() are relevant documents for reference. As part of the technical feasibility assessment, an airborne equipment functionality and performance validation should be performed to determine whether the airborne equipment under the relevant airline fleets supports the GBAS functionality and performance.

The following document provides useful information for siting a GBAS installation:

- Siting Criteria for Ground Based Augmentation System (FAA Order 6884.1)

iv. VDB Frequency Application and Assignment

The GBAS makes uses of GNSS to provide precision landing with benefits of enhancing safety and operational efficiency. In a typical GBAS installation, a VHF data broadcasting (VDB) radio shall be installed at the vicinity of the airport to broadcast the correction message to the aircraft for the provision of precision approach service. According to the ICAO SARPs, GBAS operates in the frequency band 108 – 117.975 MHz. The lowest assignable frequency is 108.025 MHz and the highest assignable frequency is 117.950 MHz. The frequency spectrum and channel plan of the VDB is the same as the VOR and ILS LOC.

With reference to ICAO Doc 9718 Vol. II, the channel spacing for a VDB should have minimum of 1 MHz channel spacing from any existing VOR, ILS LOC or other VDB within a defined range, which is the range where no interference is anticipated. Based on this range and the plus or minus 1 MHz channel spacing requirement, a VDB frequency must be assigned so that there will be no harmful interference from and to other VHF sources including VOR, ILS LOC, VHF COM, and FM broadcast. As such, States should take a holistic approach for frequency assignment to GBAS VDB, VOR, and ILS LOC.

There are two aspects of consideration in frequency assignment and deployment for GBAS VDB:

(a) Same-airport compatibility
(b) Airport-to-airport compatibility

The same-airport compatibility refers to the compatibility with VHF facilities in the same airport where the GBAS is installed. It involves analysis on impact/interference among VHF facilities on aircraft, GBAS VDB facilities and other airport VHF facilities, including the consideration of minimum separation of VDB transmitter antenna from aircraft to avoid saturation of VHF receiver on aircraft. It would mainly be the matter of siting criteria for GBAS VDB ground facilities and is not relevant to frequency coordination.

The airport-to-airport compatibility is the frequency compatibility of VDB with other VHF facilities outside the airport where the GBAS is installed. The coordination would not only be within the State/Administration but should only work out with neighboring States/Administration associated with the Designated Operational Coverage (DOC) to ensure no adverse impact due to any interference from and to other VHF sources aforesaid. Such consideration is described in the ICAO Handbook on Radio Frequency Spectrum Requirements for Civil Aviation (Doc 9718) Vol. II, with the following principles:

(a) The ratio of the desired-to-undesired power (D/U ratio) must be greater than a threshold.

(b) The D/U ratio threshold is defined as a function of the frequency separation, but it is also a function of the power input to the receiver. It is -60 dB for 1 MHz separation with sufficiently low power.
(c) The power of the undesired signal must be lower than a threshold.
(d) The D/U ratio can be assessed at the edge of the declared operational coverage where the desired power will be minimum.
(e) The power of signals can be estimated as per the ITU propagation curve (ITU-R Recommendation)

Assuming that the radius of the DOC is 23 NM which is the nominal value for GBAS, the above criteria are safely satisfied when the frequency separation is 1 MHz or more and the geographical separation is 30 NM or more. Furthermore, a real shape of the service volume of the GBAS could be considered, because the potential interference may occur outside the intended service volume. It should be noted that the minimum service volume as defined in the ICAO Annex 10 is not a circular area but is a "keyhole" shape (see ICAO Annex 10 Attachment D Figure D-5).

V. Concept of Operations Development (CONOPS)

A Concept of Operations (CONOPS) is a description of the characteristics of the service from the users' (such as airline staff and air traffic controllers) perspectives. The CONOPS should state the goals, strategies, policies and constraints affecting the service. It should include a clear statement of responsibilities of involved participants and stakeholders. Chapter 7.3 in ICAO Doc 9849 GNSS Manual provides reference about the elements, considerations and stakeholders involved for the development of CONOPS. The outcomes of the analysis should culminate in the development of a CONOPS document that is distributed to all potential stakeholders including however not limited to ATC operations, maintenance, safety, and procedures design. The Concept of Operations is a useful document to enable all stakeholders to understand how the GBAS will be used within the existing ATM environment and the development of Operational Requirements.

Based on the outcome of analysis of first three phases listed above (Operational Need Analysis, Cost-Benefit Assessment and Technical Feasibility Assessment), the State may finally decide to introduce GBAS based operation at its airports. The final outcome of analysis should culminate in the development of a CONOPS document that is distributed to all potential stakeholders including however not limited to ATC operations, aerodrome operator, airline operators, airspace management, regulatory authority, maintenance, safety, and procedures design. The Concept of Operations is an useful document to enable all stakeholders to understand how the GBAS will be used within the existing ATM environment and the development of Operational Requirements.

The State could form a GBAS Implementation Team comprising of members from the regulatory and service provider organizations as well as user representatives including however not limited to ATC operations, aerodrome operator, airline operators, airspace management, aeronautical information services, maintenance, safety, and procedures design. A wide participation by representatives in a cross-sections manner can consolidate comprehensive views in developing strategic guidance and detailed recommendations on GBAS implementation.

A common goal of a regulator and service provider is to ensure that aircraft operators receive the benefits of GBAS based services in a timely and effective fashion while maintaining high standards of safety. The GBAS implementation team supports this goal by fostering a cooperative approach to the development of the standards, systems, procedures as well as the terms and conditions for regulatory approvals that respond to the needs of the aviation community.

Regulating GBAS and providing GBAS-related services require that various branches in the regulatory and service provider organizations allocate resources to specific tasks. A key goal of a GBAS implementation team is to identify resource requirements and to deploy resources for effective implementation.

vi. GBAS Solution Selection

Once a preliminary site has been identified, there are a number of different GBAS solutions available in the market to support the delivery of a GLS service. Careful consideration and selection of the most appropriate solution is essential to ensure that the expected benefits are realised. The following provides high level guidance when selecting a GBAS product:

- States should ensure that the product conforms with ICAO Annex 10, Volume 1 Standards and Recommended Practices for a GBAS and that any non-conformances have been appropriately assessed and accepted;
- States should consider whether the proposed solution has previously been certified by another State. Previous certification may allow States to leverage the existing certification evidence to expedite the regulatory approvals process and simplify any developmental processes;
- Nominally certification involves demonstration that the product meets a particular specification published by a State. If States intend on utilising an existing product that has previously been certified by another State, then States should assess:
    - if the specification used to develop the certified GBAS product is suitable for use in the local region, of which conditions are identified in the technical feasibility assessment phase, Section 5.b.iii). This should involve a comprehensive analysis of each of the requirements contained within specification to determine the extent of applicability and if determined to be either partially applicable or not applicable, alternative requirements should be developed.
    - any waivers and deviations to the specification used to develop the certified GBAS product and whether those waivers and deviations are acceptable for the local region.
- States should consider the development pathway for the product and whether the development pathway aligns with the intended operational objectives;
- States should consider developing a set of site specific requirements that are unique to the particular location at which the solution is intended to be deployed. Key site specific requirements may include:
    - Operational Requirements (key ATC requirements)
    - Legislative requirements
    - Work Health & Safety requirements
    - Civil Works specific requirements
    - Monitoring and integration requirements
    - Installation specific requirements

  - Maintenance requirements.
- when selecting a GBAS solution, States should also consider who will be responsible for the design, installation, operation and ongoing maintenance of the facility and ensure that any applicable requirements have been developed and integrated into a Statement of Work
- States should establish appropriate assessment criteria against which all GBAS products will be assessed.

vii. Site Deployment

Once a product has been selected, key activities to be performed include:

- **Site design**. The site design may involve:
  - finalising the installation location for the GBAS. This should include addressing any unique product requirements pertaining to the siting of the GBAS. As an example, some manufacturers may impose restrictions on the proximity of the antennas to runway/taxiway or distance to the furthest Decision Height Point.
  - developing the Civil Works design and obtaining approvals that the drawings comply with local legislative requirements.
  - integration design (how the GBAS will integrate with existing ATM systems).
- **Equipment installation**. This will primarily involve performing the Civil Works in accordance with the approved design drawings, installation of communications and power infrastructure, and installation of the GBAS equipment in accordance with the manufacturers manuals.
- **Integration with existing Air Traffic Management Systems.** This will primarily involve integrating the GBAS with other ATM systems including providing GBAS status monitoring to Maintenance and Operations.
- **Verification Activities**
  - **Factory Acceptance Testing**. Prior to the installation of the GBAS, States may elect to perform a Factory Acceptance Test to verify that the product conforms with the State's specification.
  - **Site Acceptance Testing.** Post installation, Site Acceptance Testing will nominally involve verifying the system is performing as per the requirements, has been installed in accordance with the approved documentation and manufacturers manuals.
  - **Flight Inspection.** Prior to Commissioning, a Flight Inspection should be completed. Details about flight inspection are provided in Section xi.
- **Operational Test & Evaluation.** Prior to Commissioning the GBAS for full operational use, States may elect to perform an Operational Test & Evaluation program. The Operational Test & Evaluation program may involve independent monitoring of the GBAS signal in space and/or approved aircraft operators flying GLS approaches in controlled conditions to validate the service is operating as intended.

viii. Airport Height Restriction Plan Amendment

In order to protect the GBAS ground segment from unauthorised developments or intrusions that may impact on the performance of the GBAS, a comprehensive protection area should be established around the GBAS site. The area should be designed to protect:

- GNSS satellite reception and tracking at each of the Reference Receivers

- VDB coverage particularly within the Approach Service Volume for each runway.

Depending on the location of the GBAS, restrictions may additionally be imposed on vehicle and/or aircraft movements within the vicinity of the GBAS. These will be site dependent and should be established and verified as part of site deployment.

The following provide examples of protection areas implemented by other States.

- FAA Order 6884.1 – Siting Criteria for Ground Based Augmentation System (GBAS)

ix. Operational Considerations

When deploying a GBAS it is important that States consider changes to existing practices for ATC and procedures design staff. The following provides guidance on key areas to consider with the introduction of a GBAS:

- any changes to sectorisation or airspace (introduction of a first of type precision to a runway or extension of the GBAS Approach Service Volume may require airspace changes)
- any changes to practices for processing traffic
- any changes to phraseology
- any changes to separation standards
- any changes to the information provided to pilots
- any changes to existing documentation including any local instructions or training documentation
- changes to workstations and equipment
- changes to Human Machine Interfaces.

x. GBAS Instrument Flight Procedure Design

GBAS Instrument Flight Procedures, also named as GLS Procedures, are designed as per the provisions of ICAO DOC 8168 VOL II (Chapter 6 in Section 3 of Part III) by authorized procedure designers using available tools with latest survey reports and Obstacle & Terrain data. The two key outputs of the Procedures Design process are the corresponding Instrument Approach Procedure Chart and Final Approach Segment (FAS) Data Block. The FAS Data Block contains the information detailed within ICAO Annex 10, Volume 1 defining the final approach path. Validation of the parameters contained within the FAS Data Block is critical to assuring the safety of the approach. Flight Validation may be carried out for each GLS procedure either on a simulator or actual flight.

The GLS procedure design criteria defined in Doc 8168 Vol-II are based on ILS criteria and are related to the ground and airborne equipment performance and integrity required to meet the operational objectives described in Annex 10.

The procedure from en-route to the GLS final approach segment and in the final missed approach phase conforms to the general criteria. The differences are found in the physical requirements for the GLS precision segment which contains the final approach segment as well as the initial and intermediate phases of the missed approach segment. These requirements are related to the performance of the GBAS system.

RF turn to the final approach course - The intermediate approach segment may incorporate a PBN route ending with a radius-to-fix turn to the final approach course. In this case, the RF turn shall terminate at a waypoint located on the final approach course. The position of this waypoint is considered as the point of localizer interception.

The FAS data block is prepared by the procedure designer and the accuracy of the path is dependent on the accuracy and integrity of the original data on the runway and calculations carried out by the designer. The final approach path parameters are designed using geodetic and geometric calculations and the parameters are formatted into a FAS data block in electronic media with a cyclic redundancy check (CRC). To insure the integrity of the data, the complete block is transferred electronically to users for inclusion of the path data in the GBAS system for transmission to user airborne systems.

A complete description of the FAS data block is included in Doc 9368, Instrument Flight Procedures Construction Manual, Attachment C.5, along with an example of the process and product.

The current ILS Collision Risk Model (CRM) may be used to arrive at an optimum OCA/H until specific GBAS distributions for the existing CRM are developed.

Glide path verification check - A fix at the FAP is necessary so as to permit comparison between the indicated glide path and the aircraft altimeter information.

Validation of GLS procedures could take reference to relevant information stipulated in ICAO Doc 9906 Volume 5 Validation of Instrument Flight Procedures.

xi. Flight Inspection

A Flight Inspection is nominally performed as part of Site Acceptance Testing and prior to Commissioning. Successful completion of the Flight Inspection is critical to assure that the system is operating as intended and any restrictions on the use of the GBAS have been appropriately identified and promulgated.

The primary intention of conducting a GBAS Flight Inspection is to verify that VHF Data Broadcast (VDB) field strength requirements are met throughout the GBAS Approach Service Volume defined in the ICAO Annex 10, Volume 1 Standards and Recommended Practices and identify any interference or degradation to the GBAS signal in space.

Flight Inspection of GBAS additionally serves as a means to conduct a Position Domain Functional Check and a check of the Final Approach Segment (FAS) Data. The Position Domain Functional Check however is not intended to provide a statistical confidence level of the position measurement as GNSS errors change over time as detailed in ICAO Annex 10, Volume 1.

Some States additionally include a requirement to Flight Inspection for GBAS at routine intervals. The intervals is at the discretion of the State. The primary intention of routinely Flight Inspecting a GBAS is to detect changes to the environment surrounding the site that may impact on VDB coverage. Additionally, routine Flight Inspection serve as a means to validate that the Airport Height Restriction Plan is appropriately protecting the GBAS from unauthorised intrusions and developments.

Further guidance material on Flight Inspecting the GBAS is available in the following documents:

- ICAO Doc 8071, Volume 2, Testing of Radio Navigation Aids

xii. Logistics Support

In order to support the GBAS post implementation, States should ensure that appropriate Support Systems have been established to provide continuous maintenance and operation. This may include:

- **Maintenance Support**. Maintenance Support should be performed by appropriately trained qualified and experience staff or delivered by the manufacturer. Maintenance Support may encompass regular performance inspections of the GBAS ground equipment and support infrastructure to verify the GBAS is operating in accordance with prescribed performance requirements and corrective maintenance activities. The Maintenance Support environment should ensure that there is an adequate level of spares available to meet Availability requirements and appropriate systems in place to record maintenance related issues. Timeliness of the response to all maintenance requirements should also be addressed.
- **Engineering Support**. Engineering should be performed by appropriately trained, qualified and experience staff or delivered by the manufacturer. Engineering Support may encompass configuration management of the system, investigation of complex faults and failures, ongoing monitoring of GBAS performance and system enhancements.
- **Supply Support**. Supply Support should ensure that there is adequate manufacturer support in place for ongoing logistics support including investigation of complex faults and failures, repair of equipment, and supply of additional spares.

xiii. Training

The introduction of GBAS in any State represents a significant change for aviation, so it requires new approaches to regulation, provision of services and operation of aircraft, and personnel training is the key for the success of implementation.

A Training Needs Analysis should be completed by States to identify the training needs for all stakeholders involved in the operation, use and maintenance of the GBAS. Stakeholders that should be included within the analysis include ATC staff, maintenance staff, engineering staff, pilots, and procedures designers.

The Training Needs analysis should:

- identify of the impact of GBAS implementation to the stakeholder and a determination of any delta training required;
- include an analysis of the skills and knowledge required to install, certify, operate and/or maintain the GBAS ground facility and GBAS based services; and
- include training resources, methods and delivery requirements.

The following provides examples of training delivered for GBAS by other States:

- **General Awareness training.** General awareness involve training on the overview of GNSS and Augmentation systems, principles of operation of a GBAS, differences between an ILS and GBAS based precision approach, the limitations and advantages of a GBAS, and should be provided to all stakeholders.
- **ATC.** ATC staff should be provided with a briefing on the GBAS, changes to local instructions as a result of the introduction of a GBAS, changes to the information contained within a Flight Plan, any changes to endorsements/ratings, interpretation of

GBAS monitoring indications, and training on any new systems introduced to support delivery of a GLS approach capability.

- **Regulators.** Regulators should be provided with general awareness training and the training pertaining to applicable SARPs for updating the regulation to include GBAS operations.
- **Maintenance**. Staff responsible for maintaining the GBAS should be provided with training on the fundamental principles of operation of a GBAS, specific equipment, operation of the equipment and maintenance practices for the equipment including routine maintenance activities to be performed and procedures for investigating of faults and failures. States may elect to develop a set of GBAS competency criteria against which the competency of maintenance staff would be assessed.
- **Engineering.** Staff responsible for Engineering Management of the GBAS ground facility should be provided with training on advanced GBAS concepts, configuration management of the GBAS, fault detection, and complex fault analysis/resolution.
- **Pilot**. Pilot training will be driven by the airline and specific aircraft type. Pilot training may involve a differences course between GBAS and ILS and corresponding simulator training.
- **Procedures Design.** Instrument Flight Procedure Designers may be provided with supplementary training on the differences between GBAS and ILS and information contained within a Final Approach Segment (FAS) data block.

xiv. Development of Regulations Related to GBAS for Aviation

Regulators, service providers and aircraft operators should all ascertain that a GBAS based operation is safe before it is introduced. This requires a systematic use of engineering and management tools to identify, analyse and mitigate hazards during all phases of the system's life cycle. The process is defined as a given task to be performed by a combination of people, procedures, technologies (hardware and software) and data within a given environment.

It is necessary to have a common understanding among all the relevant aviation stakeholders regarding the GBAS implementation and GBAS based services/procedures being utilized in civil aviation.

It is State's responsibility to authorize the GBAS ground facility to be used for provision of GBAS based services.

It is also State's responsibility to authorize the aircraft operators to conduct GLS procedures based on the aircraft certified and approved GBAS capability. The aircraft's on-board GBAS equipment certification is normally documented in the aircraft flight manuals and / or flight crew operations manuals.

Regulations related to GBAS in civil aviation:

- Any GBAS ground facility installed at and/or in the vicinity of airport shall not be used for the provision of GBAS based services unless certified by the regulatory authority of the State.
- Any GBAS based service/procedure shall not be put into use for civil aviation purposes unless approved by the regulatory authority of the State.
- The details of GBAS ground facility installed at and/or in the vicinity of airport including GBAS based service/procedure shall be published in AIP.

- Any aircraft shall not utilize the GBAS based service/procedure unless the avionics requirement in terms of GBAS receiver equipage, pilot training requirements etc. are being met, as prescribed by the regulatory authority of the State.
- On-board GBAS receiver shall be certified by the regulatory authority of the State.
- The GBAS service provider shall carry out system check and operational performance monitoring on a continuous basis. The reports in respect of accuracy, integrity, availability, and continuity should be prepared and shared with the regulator on a periodic basis. Any major degradation in service or breach of terms and conditions may lead to withdrawal/cancellation of certificate/approval.
- The State may develop Inspection checklist for the purpose of certification of GBAS ground facility.
- The State may develop compliance checklist for the purpose of granting approval to GBAS based services/procedures.
- The State should develop the certification methodology, which may include re-certification criteria, revocation of certificate for GBAS ground facility, stating the certification process, regulatory requirements, period of validity, terms and conditions etc.
- The State should also develop the approval and withdrawal process for GBAS based services/procedures.

An important issue during implementation of GBAS is certification and operational approvals that are dependent upon the State's national regulations. The regulator should be involved right from the first phase of GBAS implementation process (i.e. Operational Need Analysis) along with the other stakeholders for smooth conduct of certification process.

The common steps in certification are: System Design Approval, Facility Approval and Operational Approval.

System design approval (SDA) refers to the certification of the system as a product. Each state may have a procedure to do all the SDA or validate the SDA done by another country.

Facility approval refers to the certification of the installation, with the compliance with all the requirements of the product installed in a specific location and condition.

Operational approval refers to proper operation, and involves existence of regulations, personnel training and all operational process defined and documented.

All the three approvals may follow six-phase certification process:

- **Phase One: Pre-Application.** The Air Navigation Service Provider (ANSP)/aerodrome operator ("Operator") and relevant stakeholders should convene a meeting with the regulator (pre-application meeting) for ascertaining all the requirements to be met, during the approval process.
- **Phase Two: Formal Application.** The Operator should submit the formal application to the regulator, accompanied with all the relevant documentation.
- **Phase Three: Review of Documentation.** The regulator should evaluate the documentation to determine their conformance with ICAO SARPs and national regulations. As a result of this review and evaluation, the regulator may accept, suggest certain changes or reject the formal application along with the documentation.

- **Phase Four: Inspection and Demonstration.** The regulator should carry out the physical inspection of GBAS ground facility and demonstration of intended capability including simulator and/or flight trial, if required. Once the regulator accepts or approves the changes made based on documentation review and the satisfactory outcome of Inspection and Demonstration, the relevant stakeholders should:

  (a) provide the respective training to its personnel; and
  (b) implement the operational demonstration.

- **Phase Five: Approval.** Once all the aforementioned steps have been completed satisfactorily, the regulator should issue the relevant approval.
- **Phase Six: Post-Implementation Review.** The Post-implementation review should be carried out and the system and operational performance should be monitored on a regular basis. The reports in respect of accuracy, integrity, availability, and continuity should be prepared and shared with the regulator on a periodic basis. Any major degradation in service or breach of terms and conditions may lead to withdrawal/cancellation of certificate.

The regulatory authority of the State of the Operator should consider issuing GBAS Landing System (GLS) operational approval to commercial air transport operators, based on aircraft manufacturer's certification of on-board GLS equipment as documented in the aircraft flight manual, operator's GLS training programmes, GLS operating procedures, maintenance arrangement, navigation database, minimum equipment list, etc. The GLS operational approval should specify any limitations on proposed operations as deemed necessary.

xv. Safety Assessment and Certification

The Safety Assessment and Certification process should fundamentally demonstrate that the Service provided will be acceptably safe during and after the implementation of the GBAS. Early engagement with the Regulator on the approach to certification and Regulatory involvement in certification activities is critical to achieving a successful outcome.

The Safety Assessment process could comprise of two key components:

- **System Safety**. This should demonstrate that the system as designed and operated in accordance with approved practices is safe. Previous certification may allow States to leverage the existing certification evidence to expedite the System Safety assessment process
- **Service Safety**. This should demonstrate that the Certified System installed within the local environment will be acceptably safe. This may include:
  - demonstration that the local ionosphere conditions are adequate to support the intended level of service
  - demonstration that there has been an adequate level of assurance that critical GBAS data has been validated
  - demonstration that local regulations and requirements have been met.

The key elements of the certification argument could comprise of:

- **Concept Defined.** Demonstration the concept of operations has been adequately defined and documented. This should address the question how will the GBAS integrate and operate within the states Air Traffic Management System.

- **Safety Management Process.** Demonstration that safety management activities have been conducted for the system as a whole and that identified hazard controls have been incorporated into the design and implementation.
- **Design and Implementation.** Demonstration that the system has gone through adequate system design and implementation process. Demonstration that the design and implementation meets legislative requirements and conforms with ICAO SARPS.
- **Support Systems.** Demonstration that the necessary sustainment systems are in place, which are adequately defined with acceptable controls in place to reduce the risk to acceptable level.
- **Operational Testing.** Demonstration that Operational Testing has been adequately defined, completed and that the level of risk is acceptable. Any lessons learnt from Operational Testing have been integrated into GBAS operations.
- **GBAS Operations.** Demonstration that GBAS landing operations are defined, Support Systems updated and the level of risk acceptable.

Once all of the elements have been addressed, a comprehensive Safety Case can be developed and presented to the Regulator.

xvi. Promulgation of Information in AIP

Upon approval from the Regulator, the information regarding implementation of GBAS and description of GBAS based services or GLS procedures should be promulgated in State's Aeronautical Information Publication (AIP) in accordance with AIRAC system.

xvii. Post Implementation Review

Subsequent to the Commissioning of a GBAS installation and after an appropriate period of operation States should consider conducting a Post Implementation Review.

The Post Implementation Review should be conducted with the following objectives:

- It should provide assurance that the residual safety risks associated with the operation of the GBAS continue to be managed to acceptable level.
- It should ensure that lessons learnt from the initial operating period are captured.
- It should be able to identify any issues experienced and remedial action to address those issues.
- It should ensure that any outstanding tasks for activities within the Safety Case have been appropriately addressed.
- It should validate that assumptions are still applicable

The Post Implementation Review should involve the review of:

- service requirements and whether the GBAS has met those Service Requirements
- operational practices for the GBAS
- implementation process and areas for improvement
- hazards associated with the operation of the GBAS and whether existing risk assessments remain valid
- any occurrences or system related issues
- any safety related issues
- whether the safety benefits envisaged from the implementation of the GBAS have been met

6. POST-IMPLEMENTATION ACTIVITIES

a. Operation and Maintenance Activities

States will be required to perform maintenance activities on a routine basis to verify the GBAS is operating within the required standards. ICAO DOC 8071, Volume 2, presents guidelines on recommended ground and airborne testing practices. Examples of maintenance activities may include:

- verifying whether the VDB transmitter frequency, VDB receiver Frequency, and VDB transmitter output Power are within tolerance limit
- verifying whether any spurious emissions emanating from the VDB transmitter are within tolerance limit
- verifying whether power in adjacent channels is within tolerance limit
- verifying whether the antenna Voltage Standing Wave Ratio is within tolerance limit
- verifying whether the ionospheric variation is within the ionospheric threat model
- checking the functionality of any GBAS monitoring systems to Air Traffic Control or Maintenance Centres
- reviewing Event Logs for any new fault conditions
- verifying functionality of any redundant power systems
- checking for any signs of damage or corrosion to the supporting infrastructure
- Routine Flight Inspections to verify VDB coverage. The requirement for and frequency of ongoing Routine Flight Inspections is at the discretion of the State.

Additionally, States should continuously monitor for changes to the satellite constellation (e.g. satellite maintenance activities) and assess the impact of constellation changes on the performance of the GBAS, specifically on availability. Furthermore, States should continuously monitor for changes to the environment surrounding the GBAS, including new developments and vegetation growth, to ensure that impacts to GBAS performance are minimised.

b. Performance Indicators Assessment

States should assess the performance of the GBAS against the Performance Indicators established in regular basis during the implementation and post-implementation phases. States may also regularly review the effectiveness of performance indicators established in evaluating the performance of GBAS.

c. Status monitoring and NOTAM

States should continuously monitor for changes to the satellite constellation and assess the impact of constellation changes on the performance of the GBAS, specifically on availability. Moreover, State ANSP have the responsibility to monitor and report the status of navigation services. To support this requirement, navigation service providers should provide status information to ATS. If the status of a navigation service changes, pilots should be advised via direct communications and/or via a NOTAM system.

Appendix 1 – Terminologies and Definition

ANSP	Air Navigation Service Provider
ATC	Air Traffic Control
ATM	Air Traffic Management
CAT I	Category I
CONOPS	Concept of Operations
CRC	Cyclic Redundancy Check
CRM	Collision Risk Model
FAA	Federal Aviation Administration
FAF	Final Approach Fix
FAP	Final Approach Point
FAS	Final Approach Segment
GBAS	Ground Based Augmentation System
GLS	GBAS Landing System
GNSS	Global Navigation Satellite System
ICAO	International Civil Aviation Organization
ILS	Instrument Landing System
LOC	Localiser
NOTAM	Notice to Airmen
RNAV	Area Navigation
RNP	Required Navigation Performance
SARPS	Standards and Recommended Practices
SDA	System Design Approval
VDB	VHF Data Broadcast
VHF	Very High Frequency
VOR	Very High Frequency Omni-directional Range

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Appendix 2 – Reference

1. *Relevant ICAO documents covering different aspects in GBAS implementation:*
    a. *Global Strategy – Global Air Navigation Plan (Dec 9750)*
    b. *Regional Strategy – Asia/Pacific Seamless ATM Plan*
    c. *General Concept - Global Navigation Satellite System (GNSS) Manual (Doc 9849)*
    d. *System Requirements and Testing*
        i. *Annex 10 Vol I – Radio Navigation Aids*
        ii. *Doc 8071 Vol II – Testing of Satellite-based Radio Navigation Systems*
    e. *Procedure Design and Validation*
        i. *Doc 8168 Vol II – Construction of Visual and Instrument Flight Procedures*
        ii. *Doc 9906 Vol V – Validation of Instrument Flight Procedures*
    f. *Operation*
        i. *Doc 8168 Vol I – Flight Procedures*
        ii. *Doc 9613 – PBN Manual*
        iii. *Doc 9849 – GNSS Manual*
        iv. *Dec 4444 – Air Traffic Management*
        v. *Doc 9734 – Safety Oversight Manual*
        vi. *Doc 9859 – Safety Management Manual*
    g. *Ionosphere*
        i. *GBAS Ionospheric Threat Model for APAC Region (APAC)*
        ii. *GBAS Safety Assessment Guidance Related to Anomalous Ionospheric Conditions (APAC)*
        iii. *Ionospheric Effects on GNSS Aviation Operations (ICAO NSP)*

2. *Relevant documents published by international organisations / States / Administrations relevant to GBAS implementation:*
    a. *RTCA DO-246() - GNSS-Based Precision Approach Local Area Augmentation System (LAAS) Signal-in-Space Interface Control Document (ICD)*
    b. *RTCA DO-253() - Minimum Operational Performance Standards (MOPS) for GPS Local Area Augmentation System (LAAS) Airborne Equipment*
    c. *EUROCAE ED-114() - Minimum Operational Performance Standards (MOPS) for GBAS Ground Facility*
    d. *FAA Order 6884.1 - GBAS Ground Facility Siting Criteria*
    e. *FAA-E-3017 - Non-Fed LAAS Specification*

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Appendix 3 – Experience shared by States/Administrations

a) Airservices GBAS Certification Journey and GBAS Implementation in ATC Perspective

[Powerpoint Materials available in ICAO Website for GBAS/SBAS Applicable Reference Documents (https://www.icao.int/APAC/Pages/Applicable-and-Reference-Documents.aspx)

Appendix 3-1 Airservices GBAS Certification Journey (https://www.icao.int/APAC/Applicable%20and%20Reference%20Documents/GBAS%20Appendix%203-1%20(Airservices%20GBAS%20Certification%20Journey).pdf)

Appendix 3-2 GBAS Implementation in ATC Perspective (https://www.icao.int/APAC/Applicable%20and%20Reference%20Documents/GBAS%20Appendix%203-2%20(Airservices%20Presentation%20-%20GBAS%20-%20ATC%20Perspective).pdf)]

b) Japanese GBAS Experience

Appendix 3-3 Japanese GBAS Experience (Attachment 1 - Appendix 3)

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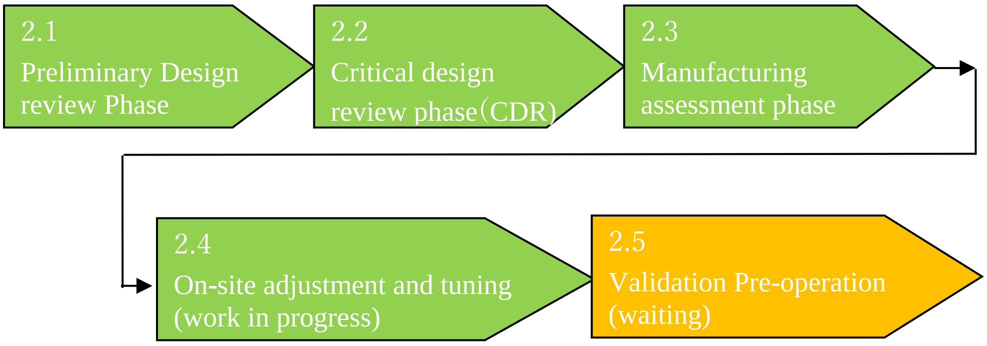
Appendix 3-3 - Japanese GBAS Experience

1. INTRODUCTION

1.1 Japan Civil Aviation Bureau (JCAB) decided CAT-I GBAS implementation at Tokyo international (Haneda) airport in 2015. JCAB awarded a contract to NEC Corporation for the design / development, production, installation of GBAS in September 2016. GBAS implementation in Haneda airport started in 2016 and the installation was completed by the end of March in 2020. (Operational trial of GBAS APCH has started at HND in July 2020.) The safety assessment of the GBAS for CAT I operations is performed in the course of the implementation process.

2. SAFETY ASSESSMENT

Safety assessments are carried out in each phase of manufacturing.



2.1 Preliminary Design review Phase

2.1.1 Safety assessment includes "safety management planning process" and "safety design". In the system safety management planning process, the equipment manufacturing contractor presents a system safety plan that clarifies the work breakdowns and their outputs at each phase. The contents are as follows.

- FHA：Functional Hazard Assessment
- FMEA：Fault Mode and Effect Analysis
- FMES：Fault Mode and Effect Summary
- CCA：Common Cause Analysis
- FTA：Fault Tree Analysis
- System Safety Assessment
- Create algorithm description document

“Safety design” is based on RTCA DO-278A, ED-109A, etc.

2.1.2 Safety assessment is carried out by the preliminary level shown in the system safety plan. And safety assessment report and algorithm description document are prepared. The system safety plan, the safety assessment report and the algorithm description document are reviewed by Technical Review Panel. Once the review is completed by the Panel, PDR is held. After all of the action items raised during PDR were closed, preliminary design is approved by JCAB.

2.2 Critical design review phase (CDR)

2.2.1 Safety assessment is carried out by the critical design level based on the system safety plan. And the updated safety assessment report and the algorithm description document reflecting the results of the PDR are submitted.

2.2.2 They are reviewed by the Technical Review Panel and CDR is held. Likewise, after all the action items raised during CDR were closed, critical design is approved by JCAB.

2.3 Manufacturing assessment phase

2.3.1 Safety assessment is carried out by the manufacturing assessment level based on the system safety plan. And the updated safety assessment report and the algorithm description document reflecting the results of CDR are submitted. They are reviewed by the Technical Review Panel and then, Manufacturing Verification Review is held. After all action items were closed, manufacturing is approved by JCAB.

2.4 On-site adjustment and tuning

2.4.1 Manufacturer verifies the safety requirements of this equipment and proves fully compliant with the requirements under operational environment. For that purpose, the equipment manufacturer prepares the safety verification practice manual. It is presented in the technical review and is reviewed by the Review Committee dedicated to on-site adjustment and tuning work manual. Then safety verification based on the manual is conducted as part of the adjustment work.

2.4.2 Function related to safety and Algorithm are confirmed by actually measured data and the results are reflected in the Algorithm description document (final version).

2.4.3 These two documents are presented and reviewed in the technical review. After all action items were closed, On-site adjustment and tuning is approved by JCAB.

2.5 Validation Pre-operation (Ongoing.)

2.5.1 After completing the on-site adjustment and tuning work, we are continuing to collect GPS data and GBAS signals to further assess their compliance with the GBAS system's safety requirements.

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