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

1. OBJECTIVES AND SCOPE OF THE GUIDANCE DOCUMENT

The objectives and scope of this document is to provide guidance on the determination of the requirement for a Satellite Based Augmentation System (SBAS) to support precision approaches at a specific airport

2. EXECUTIVE SUMMARY

Approach and landing at airports is a critical stage of flight. In adverse weather conditions, navigation guidance to support an approach provides for an additional level of safety for the activity. SBAS can provide precision approach capability.

3. ROLES AND RESPONSBILITIES OF STAKEHOLDERS

Stakeholders are responsible to provide a safe service with optimal community benefit.

4. PERFORMANCE INDICATORS

Performance indicators are quantifiable indicators got by 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 SBAS is evaluated.

[Need some examples of performance indicators for SBAS]

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 SBAS for evaluation under post-implementation review.

5. IMPLEMENTATION PROCESS FOR SBAS

a. Overview

This document is intended to provide guidance only when implementing and certifying

SBAS installation and service within the APAC region. The material contained within this document is based on the experience of other States within the APAC region, ICAO documentation, and other publicly available material.

The SBAS is a Global Navigation Satellite System (GNSS) based airspace navigation system supporting enroute to terminal airspace, consisting of the geostationary satellite and 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 to provide the required integrity, continuity, accuracy, and availability to support intended operations, such as approach procedures with vertical guidance (APV). The SBAS consists of three segments:

- Space Segment. The space segment consists of the GPS satellite constellation which provides the ranging signals and orbital parameters. Both SBAS ground facility and airborne systems use the ranging signals. The space segment also consists of geostationary satellites which relay SBAS signals generated by the Ground Segment to Airborne Segment.
- Ground Segment. The ground segment consists of:
  - a network of ground reference stations that monitor satellite signals
  - master stations that collect and process reference station data and generate SBAS messages
  - uplink stations that send the messages to geostationary satellites

  The ground segment provides:
  - differential corrections through SBAS messages to remove the range measurement errors that are common to the ground and aircraft sub-systems
  - integrity parameters to monitor and bound SBAS service integrity risk
  - optional ranging parameters to provide additional ranging signals

  An SBAS based approach does not require any SBAS infrastructure at an airport.
- Airborne Segment. The SBAS receiver on the aircraft applies the corrections to satellite ranging signals broadcast by the SBAS to obtain a position estimate with the required accuracy. The differentially corrected position is used for the intended operations. In addition, the aircraft uses integrity parameters broadcast by the SBAS ground facility to perform integrity checks on the aircraft's corrected position estimate.

b. Framework, Phases and Elements of SBAS Implementation Process

i. Operational Need Analysis

When considering whether to implement a SBAS, it is important to consider how the SBAS 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 SBAS. The analysis should involve a thorough examination of:

- current navigation capability within the airspace 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 navigation facilities with a SBAS;
- concepts for the proposed SBAS 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 SBAS; and
- a summary of the expected improvements, disadvantages and limitations of implementing a SBAS, and alternative technologies.

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

- how the SBAS 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 SBAS aligns with the overarching navigation strategy for the state;
- industry desire for a SBAS installation;
- what level of performance/service the SBAS should achieve;
- the impact of implementing a SBAS on existing ATC procedures associated with instrument approach operations including any changes to pilot interactions, phraseology, and documentation;
- how the SBAS is intended to be used within the operational environment;
- the different modes of operation for the SBAS;
- what level of SBAS 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 SBAS and any new capabilities that may need to be developed;
- what additional training is required for staff to support the implementation of a SBAS capability;
- the limitations associated with implementing a SBAS within the State including aircraft equipage rates, technology evolution, ionosphere limitations, and support capability; and
- alternative technologies available to deliver the desired capability.

The outcomes of the analysis should culminate in the development of a Concept of Operations 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 SBAS will be used within the existing ATM environment and the development of Operational Requirements. It is important for taking user segment on-board in early stage to address issues and concerns related to equipage and certification .

ii. Cost-Benefit Assessment

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

- whole of life costs associated with SBAS 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 benefits;
- 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 SBAS is equipage rates of aircraft which would directly impact usability of the technology; and
- clear articulation of the assumptions used in the cost and benefits assessment and how these impact the Business Case.

The cost benefit assessment should be conducted per three cases of implementation of SBAS:

- Full SBAS implementation (Implementation Type A)
- Participating in existing SBAS (Implementation Type B)
- Utilizing existing SBAS service (Implementation Type C)

[Need more details and deliberation on assessment for three types of SBAS]

iii. Technical Feasibility Assessment

- Full SBAS implementation (Type A)
  - Satellite (transponder) deployment
  - SBAS PRN coordination
  - SBAS ID coordination
  - Coverage and service volume
  - Service level
  - Ground monitoring station siting
  - Master station and uplink station siting
  - Robustness of communication link, ensuring acceptable availability as a part of technical feasibility study
  - Maintainability aspect of the system
  - Ionospheric impact study
- Participating in existing SBAS (Implementation Type B)
  - Review of existing SBAS services
  - Coordination with the SBAS provider
  - Coverage and service volume
  - Service level
  - Ground monitoring station siting
  - Robustness of communication link, ensuring acceptable availability as a part of technical feasibility study
  - Maintainability aspect of the system
  - Ionospheric impact study
- Utilizing existing SBAS service (Type C)
  - Review of existing SBAS services
  - Coordination with the SAS provider
  - Coverage and service volume

- Service level
- Available services

[Need more details and deliberation on these sub-items]

iv. Concept of Operations (CONOPS) Development

Based on the outcome of first three phases listed above (Operational Need Analysis, Cost-Benefit Assessment and Technical Feasibility Assessment), a State may finally decide to introduce SBAS based operation at its airports. The outcome of the first three phases should culminate in the development of a Concept of Operations (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 a useful document to enable all stakeholders to understand how the SBAS will be used within the existing ATM environment and the development of Operational Requirements. It could establish a common understanding among all parties concerned. The CONOPS included in the GNSS Manual established by ICAO NSP and the CONOPS prepared by the SBAS-IWG are already available as references as CONOPS for SBAS.

v. SBAS Solution Selection

For those areas where the use of SBAS has been determined to be beneficial, the next step is to determine which airways and runways should be prioritized for the implementation of the SBAS operating scheme. The following aspects may be considered

- Areas with inadequate DME: It is beneficial to set up a method using SBAS for air routes, approaches, and landings where ground navigation equipment such as DME is inadequate.
- Areas with inadequate radar coverage: Since RNAV cannot be set for approaches and landings without radar coverage, and only RNP can be set, it is beneficial to set up SBAS-based systems in such areas.
- Recommendation of RNP: In recent years, RNP has been recommended over RNAV, and since ground-based navigation sensors such as DME cannot be used in RNP, it is beneficial to set up SBAS methods in locations where RNP is newly set up.

vi. System Deployment (For Implementation Type A and B)

- Full SBAS implementation (Type A)
  - Satellite (transponder) deployment
  - SBAS PRN coordination
  - SBAS ID coordination
  - Ground monitoring station deployment
  - Master station and uplink station deployment
  - System testing and integration
- Participating in existing SBAS (Implementation Type B)
  - Ground monitoring station deployment
  - Coordination with the SBAS provider
  - System testing and integration

[Need more details and deliberation on these sub-items]

vii. SBAS Flight Procedure Development

When deploying a SBAS 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 SBAS:

- any changes to sectorisation or airspace
- 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

SBAS Instrument Flight Procedures are designed as per the provisions of ICAO DOC 8168 VOL II 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 Approach 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 SLS procedure either on a simulator or actual flight.

Development of SBAS (LPV) Approaches: SBAS(LPV) Instrument Flight Procedures are designed as per the provisions of DOC 8168 VOL II and ICAO PBN manual DOC 9613 by authorized procedure designer using automation tool (FPDAM) with latest survey reports and Obstacle & Terrain data.

Data requirement and acquisition for Procedure Design: Current and complete survey data and information is crucial to the design of a safe IFP. Procedure designer collects from recognized sources, validate for resolution, integrity, reference geodetic datum and effective dates. The obstacle survey for procedure design, the IFP designer shall consider that:

- All obstacles be accounted for. Items, such as trees and heights of tall buildings shall be accounted for either by physical examination of the site or by addition of a suitable margin above terrain contours; and
- The accuracy of the vertical and horizontal data obtained may be adjusted by adding an amount equal to the specified survey error to the height of all measured obstructions and by making a corresponding adjustment for specified horizontal error.

Design of Instrument Flight Procedures: Instrument Fight Procedures are designed in accordance with the appropriate design processes, standards, guidelines, and aeronautical data quality requirements contained in the following ICAO documents:

- Doc. 8168, Procedures for Air Navigation Services Volume II, Construction of Visual and Instrument Flight Procedures
- Doc. 8697, Aeronautical Chart Manual
- Doc. 9365, Manual of All-Weather Operations
- Doc. 9613 Performance Based Navigation Manual — Volume I Concept and Implementation Guidance, and Volume II Implementing RNAV and RNP
- Doc. 9905 Required Navigation Performance Authorization Required (RNP Procedure Design Manual
- Doc. 9881, Guidelines for Electronic Terrain, Obstacle and Aerodrome Mapping Information
- Doc. 9906, Quality Assurance Manual for Flight Procedure Design
- ICAO Doc. 10066, Aeronautical Information Management

viii. Flight Check

A Flight Check can be considered to address the performance of the SBAS (Flight Inspection) and also the flyability of the approach procedure (Flight Validation). A Flight Inspection is nominally performed as part of Site Acceptance Testing and prior to Commissioning. Successful completion of the Flight Inspection is a critical to assure that the system is operating as intended and any restrictions on the use of the SBAS have been appropriately identified and promulgated. The primary intention of conducting a SBAS Flight Inspection is to verify that SBAS signal strength requirements are met throughout the SBAS Service Volume defined by the State and identify any interference or degradation to the SBAS signal in space. Some States additionally include a requirement to Flight Check of SBAS at routine intervals. Flight validation of the approach procedure may also be required to confirm that the procedure is flyable for all aircraft categories that will use the SBAS for approaches.

ix. Safety Assessment

The Safety Assessment and Certification process should fundamentally demonstrate that the Service provided will be acceptably safe during and after the implementation of the SBAS. 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 SBAS data has been validated
    - demonstration that local regulations and requirements have been met.

x. System Certification

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 SBAS integrate and operate within the states Air Traffic Management System.

- Safety Assurance. Demonstration that safety assurance 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 level of risk to As Low As Reasonably Practicable.
- 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 LPV operations.
- LPV Operations. Demonstration that LPV operations are defined, Support Systems updated and the level of risk acceptable.
- Involvement of civil aviation regulatory authority early in the program is useful from system certification point of view.

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

xi. Development of Regulations Related to SBAS for Aviation

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

Regulations related to SBAS in civil aviation:

- SBAS shall not be used for the provision of SBAS based services unless certified by the regulatory authority of the State.
- Any SBAS 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 SBAS installation including SBAS based service/procedure shall be published in AIP.
- Any aircraft shall not utilize the SBAS based service/procedure unless the avionics requirement in terms of SBAS receiver equipage, pilot training

requirements etc. are being met, as prescribed by the regulatory authority of the State.

- On-board SBAS receiver shall be certified by the regulatory authority of the State.
- The SBAS 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 SBAS facility.
- The State may develop compliance checklist for the purpose of granting approval to SBAS based services/procedures.
- The State should develop the certification and re-certification methodology including revocation of certificate for SBAS, stating the certification process, regulatory requirements, period of validity, terms and conditions, if any.
- The State should also develop the approval and withdrawal process for SBAS based services/procedures.

An important issue during implementation of SBAS 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 SBAS 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 should follow six phase certification process:

- Phase One: Pre-Application. The aerodrome 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 cahnges or reject the formal application along with the documentation.
- Phase Four: Inspection and Demonstration. The regulator should carry out the physical inspection of SBAS 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:
  - provide the respective training to its personnel
  - 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.

It is necessary to have a common understanding among all parties concerned by preparing various notices indicating the flow and necessary procedures to be followed in order to provide for the operation of the system.

Regulation for SBAS Service Providers

- Any new SBAS wishing to broadcast SBAS must register and obtain approval from the ITU, as well as coordinate frequencies with other countries.
- When a new SBAS is to be provided, the SBAS coverage and service area shall be designated and a report shall be made to the ICAO NSP on the status of

compliance with SARPs and exemptions to SARPs.

- Provide a specific implementation plan and implementation methodology for each section of this guidance and obtain approval from the Regulator.

Regulation for Airlines

- For each aircraft: Whether or not the aircraft is equipped with an onboard SBAS receiver and whether or not it is compatible with the operation method shall be described.
- For each type of aircraft: The operation method to which SBAS is applied shall be clarified for each type of aircraft, and the necessary operation methods shall be described in the AOM.
- For each operator: Specific implementation methods for each section of this guidance shall be described in in-house manuals, etc.

xii. Training

The introduction of SBAS 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 SBAS. 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 SBAS implementation to the stakeholder and a determination of any delta training required;
- include an analysis of the skills and knowledge required to operate and/or maintain the SBAS; and
- include training resources, methods and delivery requirements.

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

- General Awareness training. General awareness involve training on the principles of operation of a SBAS, differences to an ILS, the limitations and advantages of a SBAS, and should be provided to all stakeholders.
- ATC. ATC staff should be provided with a briefing on the SBAS, changes to local instructions as a result of the introduction of a SBAS, changes to the information contained within a Flight Plan, any changes to endorsements/ratings, interpretation of SBAS monitoring indications, and training on any new systems

introduced to support delivery of a SLS approach capability.

- Maintenance. Staff responsible for maintaining the SBAS should be provided with training on the fundamental principles of operation of a SBAS, 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 SBAS competency criteria against which the competency of maintenance staff would be assessed.
- Engineering. Staff responsible for Engineering Management of the SBAS should be provided with training on advanced SBAS concepts, configuration management of the SBAS, and complex fault analysis.
- Pilot. Pilot training will be driven by the airline and specific aircraft type. Pilot training may involve a differences course between SBAS and ILS and corresponding simulator training.
- Procedures Design. Instrument Flight Procedure Designers may be provided with supplementary training on the differences between SBAS and ILS and information contained within a Final Approach Segment (FAS) data block.

xiii. Operation Certification

Certification and approvals for operation must be obtained before it can be put into operation.

Certification for SBAS Service Providers:

- As an SBAS service provider, the SBAS service provider shall be confirmed to be in conformance with SARPs Annex 10, and shall obtain approval.
- Obtain approval after confirming that the SBAS scheme design conforms to SARPs Annex 14, 15, etc., and that the scheme has been designed and appropriately evaluated in the manner required by PANS-OPS, etc.

Certification for Airlines:

- As for operational approval as an airline, operational approval is required according to the ICAO PBN Manual for departure, enroute, oceanic, and landing. However, when using SBAS-CAT-I, it is outside the scope of the PBN Manual, and since it is a CAT-I operation, it is likely to be subject to the previous ILS CAT-I operational approval.

xiv. Post-Implementation Review

Subsequent to the Commissioning of a SBAS installation and after an appropriate period of operation States should consider conducting a Post Implement Review. The Post Implementation Review should involve the review of:

- Service Requirements and whether the SBAS has met those Service Requirements
- operational practices for the SBAS
- implementation process and areas for improvement
- hazards associated with the operation of the SBAS 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 SBAS have been met
- Development of performance evaluation and verification tools
- Regulatory clearance for signal up-link to SBAS GEO satellite

6. POST-IMPLEMENTATION ACTIVITIES

a. Operation and Maintenance Activities

[Need further inputs from States and supplementary information about Operation and Maintenance Activities for SBAS]

b. Performance Indicators

States should assess the performance of the SBAS 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 SBAS.

Appendix 1 – Terminologies and Definition

ATC	Air Traffic Control
ATM	Air Traffic Management
CAT-I	Category I
CONOPS	Concept of Operations
FAS	Final Approach Segment
GNSS	Global Navigation Satellite System
ICAO	International Civil Aviation Organization
ILS	Instrument Landing System
RNAV	Area Navigation
RNP	Required Navigation Performance
SARPS	Standards and Recommended Practices
SBAS	Satellite Based Augmentation System
SDA	System Design Approval

[To be finalised]

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Appendix 2 – Reference

1. *Relevant ICAO documents covering different aspects in SBAS 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. *SBAS Safety Assessment Guidance Related to Anomalous Ionospheric Conditions (APAC)*
      ii. *Ionospheric Effects on GNSS Aviation Operations (ICAO NSP)*

2. *Relevant documents published by international organisations / States / Administrations relevant to SBAS implementation:*
   a. *RTCA DO-229F - Minimum Operational Performance Standards for Global Positioning System/Wide Area Augmentation System Airborne Equipment*

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Appendix 3 – Experience Sharing by States/Administrations

(a) GAGAN – Indian SBAS

Satellite Based Augmentation (SBAS)

1 Introduction

All navigation and approach aids (NAVAIDs) must meet the requirements of accuracy, continuity, availability and integrity specified to each phase of flight.

As the air traffic flow increased, the conventional NAVAIDs were not able to provide the flexibility in airspace to absorb this growth fitting the needs of the requirements referred so above.
The development, initially by the United States, of a global system providing positioning and timing services allowed the introduction of an alternative to those conventional NAVAIDs with the possibility of using new concepts in air navigation capable of satisfying the new needs of the aeronautical community.

As the development of new concepts and systems occurred, the International Civil Aviation Organization (ICAO) introduced the Global Navigation Satellite System (GNSS), which allows navigation in all phases of flight and precision approach and, according to Volume 1 of Annex 10 to the Convention on International Civil Aviation (from here on referred to as Annex 10, vol.1), is comprised by:

I. Global Positioning System (GPS) that provides the Standard Positioning System (SPS);
II. Global Navigation Satellite System (GLONASS) that provides the Channel of Standard Accuracy (CSA) navigation signal;
III. Aircraft-based augmentation system (ABAS);
IV. Ground-based augmentation system (GBAS);
V. Ground-based regional augmentation system (GRAS)
VI. Aircraft GNSS receivers.

The list above presents position generation systems (the core constellations), receivers (with these two groups always present in navigation), and augmentation systems, which will be present when the core constellations cannot support alone the requirements for the phase of flight.

2 Global Navigation Satellite System (GNSS)

As was briefly presented in the introduction, GNSS comprises the core constellations (GPS and GLONASS), ABAS, GBAS, SBAS and GNSS receivers.

In order to increase the understanding of SBAS and put it into the GNSS context, it is important to describe the other components of the system.

2.1 Core Satellite Constellations

This is, together with the receivers, the basic part of the GNSS. According to Annex 10, two core satellite constellations have Standards and Recommended Practices (SARPs) incorporated: the GPS from United States of America and the GLONASS from the Russian Federation. There are two other constellations under development: GALILEO (European) and COMPASS (Chinese).

GPS and GLONASS have the capability to provide accurate position and time information worldwide. The accuracy provided by both systems meets aviation requirements for en-route through non-precision approach, but not the requirements for precision approach.

Considering the importance of the core constellations, according to Annex 10, any change in the SARPs that requires the replacement or update of GNSS equipment require a six-year advance notice. Similarly, a six-year notice is required of a core or augmentation system provider who plans to terminate the service provided.

2.2 GNSS Receivers

A GNSS receiver consists of an antenna and a processor which computes position, time and, possibly, other information depending on the application. Measurements from a minimum of four satellites are required to establish three-dimensional position and time. Accuracy is dependent on the precision of the measurements from the satellites and the relative positions (geometry) of the satellites used.

2.3 Augmentation Systems

Even though the core constellations and the receivers can provide accuracy, continuity, availability and integrity to meet from en-route to non-precision approach (NPA) requirements, for precision approach and procedures that require a greater degree of accuracy or integrity, it is necessary to have some source of augmentation for these parameters.

The augmentation systems that are listed in Annex 10 SARPs are ABAS, GRAS, **SBAS** and GBAS.

2.3.3 Satellite-Based Augmentation System (SBAS)

An SBAS augments core satellite constellations by providing ranging, integrity and correction information via geostationary satellites. The system comprises:

a) a network of ground reference stations that monitor satellite signals;
b) master stations that collect and process reference station data and generate SBAS messages;
c) uplink stations that send the messages to geostationary satellites; and
d) transponders on these satellites that broadcast the SBAS messages.

2.3.3 GAGAN – Indian SBAS

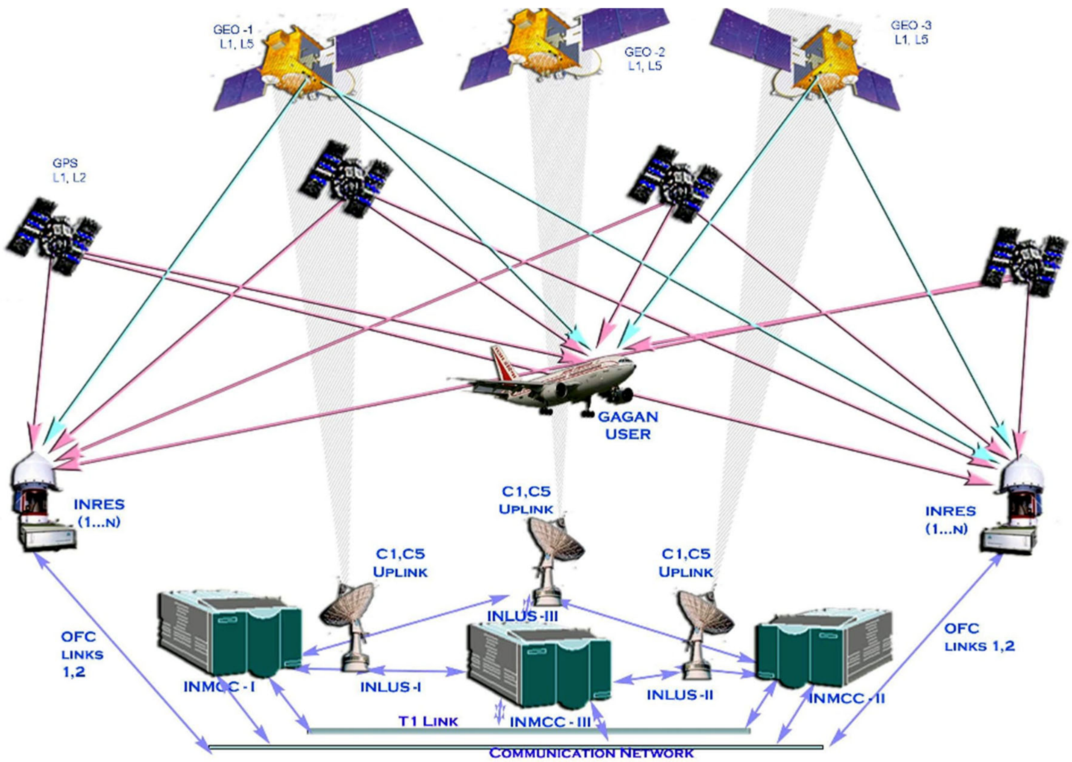
GAGAN (GPS Aided GEO Augmented Navigation) is an Indian Space Based Augmentation System (SBAS) jointly developed by ISRO and AAI to provide the best possible navigational services over Indian FIR (Flight Information Region) with the capability of expanding to neighbouring FIRs.

GAGAN is a system of satellites and ground stations that provide GPS signal corrections, giving better position accuracy.

GPS alone does not meet the ICAOs navigational requirements for accuracy, integrity and availability. GAGAN corrects for GPS signal errors caused by Ionospheric disturbances, timing and satellite orbit errors and also it provides vital information regarding the health of each satellite.

GAGAN provides augmented information for the GPS receivers to enhance the accuracy and reliability of position estimates.

GAGAN system's architecture has two segments, one is ground segment and the other is space segment. At present the ground segment consists of 15 reference stations spread all over India and three master control centres (two are in operation and one in shadow mode). These 15 reference stations are stationed at various fixed positions which receive GPS signals. The locations of reference stations are precisely chosen by the survey so that any errors in the received GPS signals can be detected.



The GPS information collected by these 15 reference stations is forwarded to the INMCC either by terrestrial or satellite communication network. At INMCC, GPS information is processed and correction (augmentation) messages are generated.

These correction (augmentation) messages are sent to INLUS (Indian Land Uplink Station) which further uplinks them to three geostationary communication satellites GSAT-8, GSAT-10 and GSAT-15.

The GEO satellites broadcast these correction messages on a GPS like signal.

2.3.3.1 DGCA Certification of GAGAN

The Director General of Civil Aviation (DGCA) has certified the GPS Aided GEO Augmented Navigaion (GAGAN) system for Navigation Performance level of Approach with Vertical Guidance (APV-1) over India & Required Navigation performance (RNP0.1) within Indian Flight Information Regions upto 18th July 2024.

सत्यमेव जयते

GOVERNMENT OF INDIA
OFFICE OF THE DIRECTOR GENERAL OF CIVIL AVIATION
DGCA COMPLEX, OPP. SAFDARJUNG AIRPORT, NEW DELHI-110 003

CERTIFICATE
Air Navigation Services Provider Certificate

No. ANS 2015/001

*In exercise of the powers delegated under SO-727 E and part XII-A of the Aircraft Rules, 1937 notified on 14th January, 2015, this certificate is hereby issued to **Airports Authority of India** by **The Director General of Civil Aviation***

Certifying the

GPS Aided GEO Augmented Navigation (GAGAN) System

for

Navigation Performance level of Approach with Vertical Guidance (APV-1) over India
&
Required Navigation Performance (RNP 0.1) within Indian Flight Information Regions

for a period not exceeding 60 months from the date of issue. This authorizes the certificate holder to provide the facility to operate as navigational aids to support air traffic services to all users on equal terms and conditions.

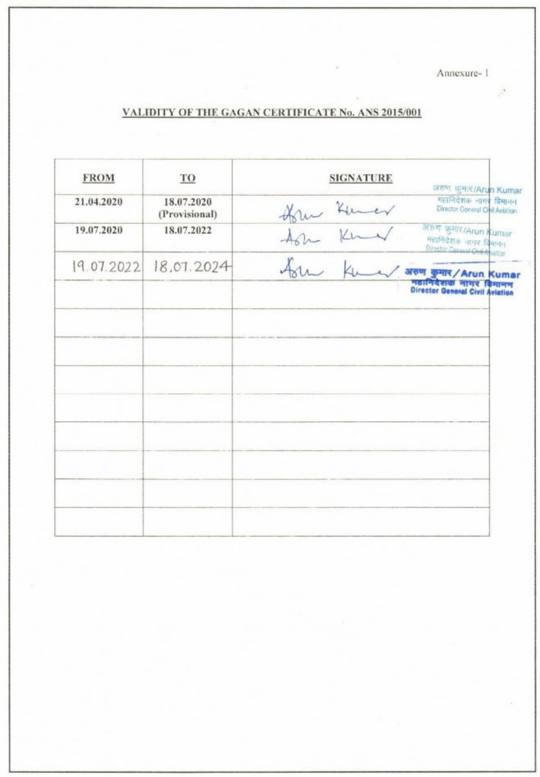
The certificate is liable to be suspended/ modified/ withdrawn or subject to any limitations or conditions, if any violation of the provisions of the Aircraft Act 1934 & the Aircraft Rules 1937, or any order/ direction/ requirements issued under the said Act/ Rules is observed.

This certificate is non-transferable.

Place : New Delhi

Date of Issue: 21.04.2015

Director General Civil Aviation



Annexure- I

VALIDITY OF THE GAGAN CERTIFICATE No. ANS 2015/001

FROM	TO	SIGNATURE
21.04.2020	18.07.2020 (Provisional)	अरुण कुमार/Arun Kumar महानिदेशक नागर विमानन Director General Civil Aviation
19.07.2020	18.07.2022	अरुण कुमार/Arun Kumar महानिदेशक नागर विमानन Director General Civil Aviation
19.07.2022	18.07.2024	अरुण कुमार/Arun Kumar महानिदेशक नागर विमानन Director General Civil Aviation

A G series NOTAM has been published on performance availability of GAGAN

G0148/15 NOTAMR G0032/14

Q) VIXX/QXXXX/IV/BO/AE/000/999/

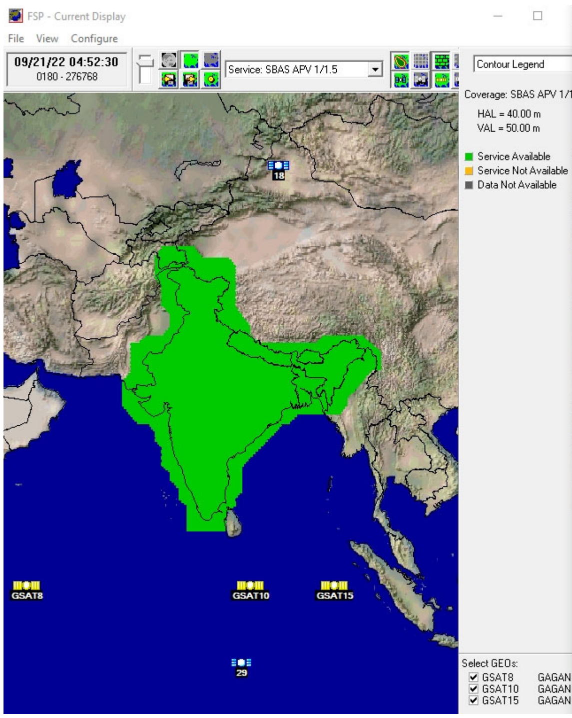
A) VIDF/VABF/VECF/VOMF **B)** 1505190530 **C)** PERM

E) REFER AIP SUPPLEMENT 48/2013. GAGAN SIGNAL-IN-SPACE AVAILABLE TO SUPPORT RNP O.1 OPERATIONS FOR EN ROUTE PHASE OF FLIGHT OVER INDIAN FLIGHT INFORMATION REGIONS AND APV 1 SERVICE OVER INDIAN LANDMASS.

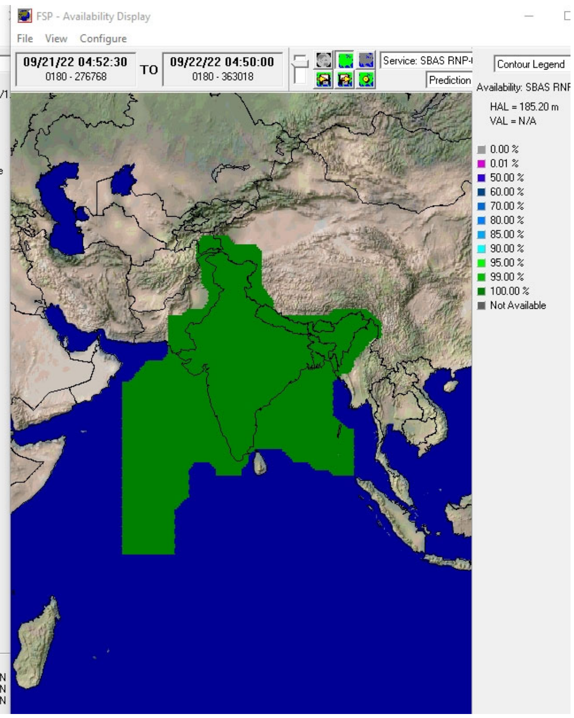
2.3.3.2 GAGAN Performance

The GAGAN is designed to achieve a performance level of APV 1.0 over the Indian land mass and RNP 0.1 over the oceanic region, within the Indian Flight Information Region (FIR).

APV-1 Performance



RNP 0.1 Performance



2.3.3.3 GAGAN Enabled Receivers

GAGAN signals are compatible with other Satellite Based Augmentation Systems like Wide Area Augmentation System (WAAS) of USA, Multi-satellite Augmentation System (MSAS) of Japan & European Geostationary Navigation Overlay Service (EGNOS) of Europe making all the systems interoperable.

To ensure global compatibility in civil aviation, the use of radio navigation aids is governed by the ICAO (International Civil Aviation Organization) Standards and Recommended Practices (SARPs). One of the most important requirements was to ensure that any properly equipped aircraft could benefit from these regional systems by installing a single receiver. RTCA Inc has developed the Minimum Operational Performance Standards (MOPS) for SBAS equipment. The main reference document is DO229 version C/D. This document describes the standards for all GAGAN/EGNOS/WAAS/MSAS receivers. Receivers complying with these requirements, as determined by the appropriate Technical Standard Order (TSO) provide full GAGAN/EGNOS/WAAS/MSAS compatibility.

2.3.3.4 Development of SBAS (LPV) Approaches

SBAS(LPV) Instrument Flight Procedures are designed as per the provisions of DOC 8168 VOL II and ICAO PBN manual DOC 9613 by authorized procedure designer using automation tool (FPDAM) with latest survey reports and Obstacle & Terrain data

2.3.3.4.1 Data requirement and acquisition for Procedure Design

Current and complete survey data and information is crucial to the design of a safe IFP. Procedure designer collects from recognized sources, validate for resolution, integrity, reference geodetic datum and effective dates.

The obstacle survey for procedure design, the IFP designer shall consider that:

a) All obstacles be accounted for. Items, such as trees and heights of tall buildings shall be accounted for either by physical examination of the site or by addition of a suitable margin above terrain contours; and
b) The accuracy of the vertical and horizontal data obtained may be adjusted by adding an amount equal to the specified survey error to the height of all measured obstructions and by making a corresponding adjustment for specified horizontal error.

2.3.3.4.2 Design of Instrument Flight Procedures

Instrument Fight Procedures are designed in accordance with the appropriate design processes, standards, guidelines, and aeronautical data quality requirements contained in the following:

a) ICAO Documents—

- **1)** Doc. 8168, Procedures for Air Navigation Services Volume II, Construction of Visual and Instrument Flight Procedures;
- **2)** Doc. 8697, Aeronautical Chart Manual;
- **3)** Doc. 9365, Manual of All-Weather Operations;
- **4)** Doc. 9613 Performance Based Navigation Manual — Volume I Concept and Implementation Guidance, and Volume II Implementing RNAV and RNP;
- **5)** Doc. 9905 Required Navigation Performance Authorization Required (RNP Procedure Design Manual;
- **6)** Doc. 9881, Guidelines for Electronic Terrain, Obstacle and Aerodrome Mapping Information; and
- **7)** Doc. 9906, Quality Assurance Manual for Flight Procedure Design.
- **8)** ICAO Doc. 10066, Aeronautical Information Management

b) Any other guideline or standard that that is applicable to a particular type of instrument flight procedure.

2.3.3.4.3 Ground Validation of Instrument Flight Procedures

Ground validation is a review of the entire instrument flight procedure package by a person(s) trained in procedure design and with appropriate knowledge of flight validation issues. The aim of ground validation is to reveal any errors in criteria application and documentation, and assess the flyability of the IFP. This process is undertaken by an authorised procedure designer other than the one who has designed the procedure.

After successful ground validation of Instrument Flight Procedure, report is submitted to DGCA along with design package for the approval of flight validation.

2.3.3.4.4 Flight Validation of Instrument Flight Procedures

Flight Validation is carried out for each procedure on simulator and on actual flight after satisfactory simulator validation.

The objectives of the flight validation of IFP are:

1) to provide assurance that adequate obstacle clearance has been provided;
2) to verify that the navigation data to be published, and the data that used in the design of the IFP, are correct;
3) to verify that all required infrastructure, such as runway markings, lighting, visual aids and communications and navigation sources, are in place and operative for a new runway
4) to conduct an assessment of flyability to determine that the IFP can be safely flown; and
5) to evaluate the charting, required infrastructure, visibility and other operational factors.

A review of the results of the Ground validation and/ or simulator evaluations is completed before the flight evaluation.

2.3.3.4.5 Approval of Instrument Flight Procedures by DGCA.

Based on Design Package, successful Ground Validation and Flight Validation DGCA accords approval for promulgation of procedure. DGCA coveys approval for each procedure in writing.

2.3.3.4.6 Promulgation of Instrument Flight Procedures.

Instrument flight procedures designs/charts, are provided for publication in the AIP/AIP Supplement in accordance with provisions contained in the documents listed below:

1) ICAO Annex 4 – Aeronautical Charts
2) ICAO Doc 8168 Volumes II - Procedures for Air Navigation Services – Aircraft Operations(PANS-OPS)
3) ICAO Doc 8697 – Aeronautical Chart Manual
4) ICAO Doc. 10066, Aeronautical Information Management