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1. Objectives and Scope of the Guidance Document

The objectives and scope of this document are to provide guidance on the implementation of a Satellite Based Augmentation System (SBAS) to support APV/precision approaches (LPV minima)* at an airport or several airports in a continent or region and some terminal and en route operations.

This document provides guidance to States when implementing SBAS, certifying SBAS installation and approving SBAS based service within the APAC region. Its material contained in this document is based on the experience of States in the region, ICAO documentation, and other publicly available material.

2. Executive Summary

The approach and landing at airports are critical stages of flight. In adverse weather conditions, navigation guidance to support an approach provides for an additional level of safety for the activity. An SBAS improves the position and timing provided by a core satellite constellation, delivering enhanced integrity, accuracy, continuity and availability. SBAS can provide geometric vertical guidance independent of QNH and temperature down to a Decision Height of 200 ft at the most rigorous performance requirements specified in ICAO Annex 10. It also enhances horizontal guidance. SBAS could replace or complement ILS at airports, and enable procedures with lower decision heights at airports without ILS. While these enhancements are most critical for approach and landing, they are present in all phases of flight including enroute and terminal operations. Furthermore, these types of approaches can also help in providing improved access to terrain challenged airports, where ILS cannot be installed due to sitting issues.

3. Roles and Responsibilities of Stakeholders

Stakeholders are responsible for providing a safe service with optimal community benefit. The stakeholders listed below have been identified:

- SBAS Operator and Maintainer – To operate and maintain the infrastructure used to generate and broadcast an SBAS signal in space to end users
- SBAS Aviation Service Provider – To provide SBAS services in a given area. (Note: The entity could be a State or group of States, regional organization, ANSP or a company. This could be the same as the SBAS Operator and Maintainer.)
- ANSP – To implement SBAS service into the ATM operations and ensure its continued safety.
- National Aviation Authority – Conduct activities as per ICAO/National/Regional Standards for SBAS service implementation
- Airspace Users – To operate aircraft safely using SBAS services
- Aerodrome Operators – To make use of SBAS services to enhance the efficiency of aircraft operations at the airport.

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* More information on instrument approach operations including APV and LPV can be found in Appendix 3.

- Flight Procedure Design Organization –To design, review, and maintain instrument flight procedures based on SBAS service in accordance with state regulations and ICAO standards, for validation and promulgation by the relevant authorities.

4. Performance Indicators

Performance indicators are quantifiable indicators obtained by measurements/statistics to show the performance or progress towards the intended result(s). Each state should consider establishing a set of performance indicators against which the performance of SBAS is evaluated under post-implementation review. Examples of performance indicators established by states in the region include:

- Conformance with accuracy, integrity, continuity, availability, and time-to-alert performance requirements as per ICAO Annex 10 for intended operations
- Status of Ground equipment such as Reference Station, Uplink Station, Mission Control Centre etc.
- Operational availability of the SBAS in ANSP's perspective under local environment
- Number of SBAS approach procedures published within the service coverage
- Number of SBAS approaches performed into the aerodrome
- Operation and Maintenance costs
- Enhancement in airport access
- Fuel saving and environmental benefit

5. Implementation Process

a. Overview

The SBAS is a Global Navigation Satellite System (GNSS) based airspace navigation system, intended to support enroute, terminal and Approach with Vertical guidance (LPV minima) operations. It consists of the SBAS satellites and ground-stations that augment core GNSS 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:

Ground Segment

The ground segment comprises a network of reference stations used to monitor signals from GNSS satellites over a vast area, region, or continent. Each ground reference station contains a GNSS receiver installed at a very accurately surveyed location. The receivers compare their range or distance to each satellite, obtained by processing the GNSS signals, to the range determined from the surveyed position of the receiver and the satellite's reported position. Any difference in the two values is reported to master stations for further processing.

Master stations process the data collected from the ground reference stations to generate corrections for clock and position of each GNSS satellite and ionospheric delay, together with integrity parameters. This information together with SBAS satellite position information is sent to satellite uplink stations for transmission to SBAS satellites in the Space Segment, from which it is broadcast to users.

Space Segment

The space segment consists of the GNSS satellite constellations which transmit the ranging signals and orbital parameters. SBAS ground reference stations and airborne systems use these ranging signals to determine their position.

The space segment also includes the SBAS satellites which relay information generated by the Master stations (SBAS messages) to airborne receivers. The SBAS satellites for the L1 SBAS service are geostationary satellites. In addition, non-geostationary SBAS satellites may be used for the dual-frequency and multi-constellation SBAS. The rent of the payloads may be subcontracted from satellite operators, like Inmarsat.

Some SBAS satellites transmit GNSS ranging signals and therefore serve as additional navigation satellites for the constellation, improving system availability.

Like the core GNSS constellation satellites, SBAS satellites are also assigned Pseudo Random Noise (PRN) codes on which SBAS messages are sent. These codes are transmitted in SBAS messages to enable GNSS receivers to determine which satellite the information is coming from.

Initially 19 PRN codes (i.e. 120 – 138) were allocated to SBAS satellites. With the increasing number of SBAS systems in service and plans for development of new systems, it was recognised that the number of codes would need to be expanded. This was done with the publication of DO-229E, where an additional 20 codes (139 – 158) were made available for SBAS.

Airborne Segment

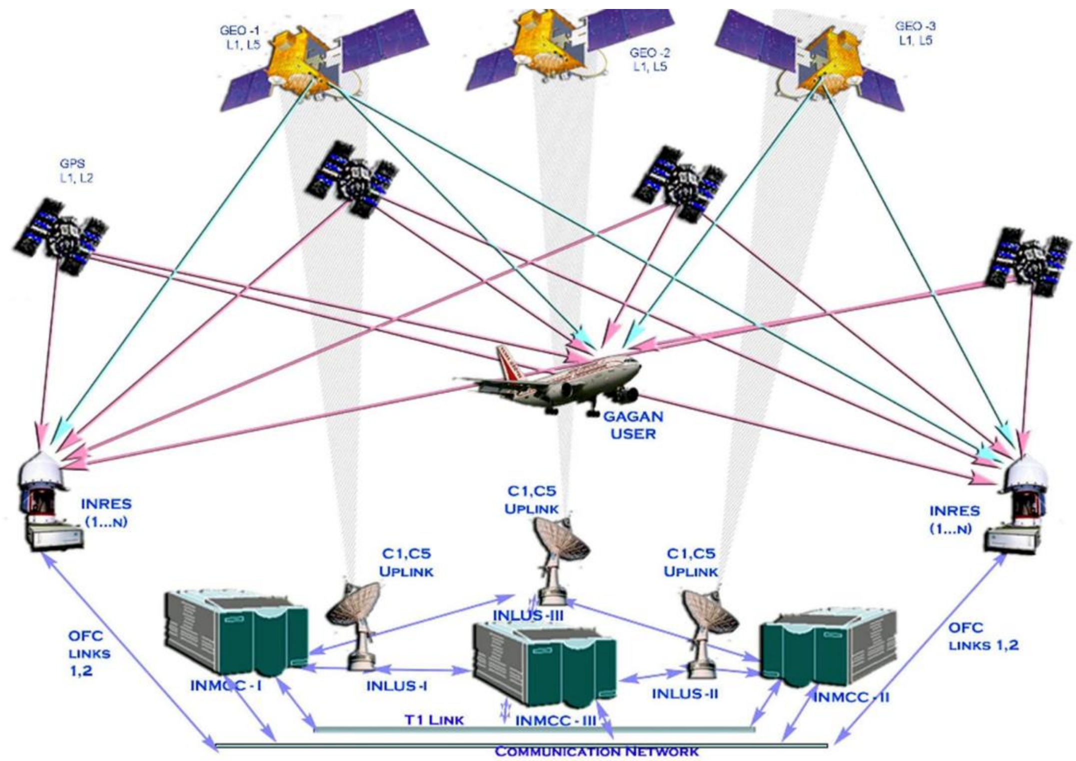
SBAS capable GNSS receivers on aircraft process the signals from the GNSS satellites and apply the corrections broadcast by the SBAS satellites to improve the accuracy of the estimated position. Airborne receivers also use information from the SBAS satellites to perform integrity checks on the aircraft's estimated position, and to calculate horizontal and vertical protection levels which are used to determine whether an intended operation (as defined in ICAO Annex 10) can be supported.

The improved performance allows the aircraft to conduct operations that require better navigation performance than the standard GNSS service can provide.

In addition to processing the GNSS signals, an SBAS capable receiver needs to receive and process the messages from the SBAS satellites. Not all GNSS receivers are SBAS capable. Standards for SBAS capable receiver are (E)TSO-C-145/146 based on RTCA DO-229D or later revisions

Technical Standard Order TSO-C145e/146e, which is based on DO-229E and includes the expanded code range, was published in May 2017. SBAS capable receivers manufactured to earlier TSOs will only recognise the original range of PRN codes (i.e. 120 – 138). Hence these receivers will not process messages from SBAS satellites using PRN codes in the expanded range (i.e. 139 – 158).

Typical SBAS Architecture (GAGAN)



b. Framework, Phases and Elements of SBAS Implementation Process

i. Operational Need Analysis

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

- existing navigation capability within the airspace including objectives, measurements of effectiveness, operational policies and constraints, existing capability description, modes of operation, and the existing support environment;
- the reasons for changing or supplementing the existing navigation facilities with an 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 organizational impacts associated with implementing an SBAS; and
- a summary of the expected improvements, disadvantages, and limitations of implementing an SBAS, and alternative technologies.

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

- the design of SBAS procedures including whether the procedures intend to overlay existing approach procedures at the airport or are new procedures in their entirety;
- how the implementation of an SBAS aligns with the overarching navigation strategy for the state;
- industry desire for an SBAS installation;
- the level of performance/service proposed to be achieved by SBAS;
- the impact of implementing an SBAS on existing ATC procedures associated with instrument approach operations including any changes to pilot interactions, phraseology, and documentation;
- the application of proposed SBAS usage within the operational environment;
- the level of SBAS status monitoring to be provided to both ATS units and airspace users;
- what the envisaged technical support environment could look like including responsibility for maintenance and engineering support;
- different types of operational uses and expected responses under each use case;
- what additional training is required for staff to support the implementation of an SBAS capability;
- the limitations associated with implementing an SBAS within the State including aircraft capabilities (such as equipage rates, and compatibility), technology evolution, ionosphere limitations, and support capability; and
- alternative technologies available to deliver the desired capability.

ii. Cost-Benefit Assessment

The cost benefit assessment should be conducted as per following three cases of implementation of SBAS against the case without SBAS:

- Full SBAS implementation (Implementation Type A)
- Participating in existing SBAS system (Implementation Type B). By adding ground reference stations to improve the service area in a given area. Simulations of the service area should be launched with the existing SBAS system to ascertain the possibility of extension of service area.
- Utilizing existing SBAS service (Implementation Type C). A neighboring State fully or partly within the service area of an existing SBAS can take advantage of the SBAS service pending an agreement be signed between the SBAS Aviation Service Provider and the State.

In addition, a cost-benefit assessment should be performed to assess the viability, i.e. whether it is cost effective to implement an 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 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.
- Identification of other non-aviation uses of SBAS and community benefits from the SBAS implementation.

There are three main benefit areas:

1. Increased network reliability –Due to possibility of Approach procedure with vertical guidance and reductions in decision heights, it may help in:

   - The increased operations to existing controlled and uncontrolled aerodromes from SBAS enabled lower approach minima and during unavailability of ILS system during maintenance or outages
   - Enabling improved access to aerodromes that do not have instrument approach procedures, by using SBAS enabled procedures
   - The positive safety impact of SBAS enabled LPV procedures at controlled aerodromes (LPV procedures are not dependent on signal broadcasted by ground equipment which could be damaged or signal could be interfered. Data integrity improvement as the Final Approach Segment is coded into a Data Block into the aircraft database with a high level of integrity through a CRC code, not dependent on QNH setting.)
   - Enhancement of performance-based navigation operations
   - Reduced costs by optimizing terrestrial radio navigation aids.
   - Possible benefits to unmanned aerial vehicle/remotely piloted aircraft system operations.
   - Recorded GNSS data in SBAS systems may be useful for accident/incident investigation.

   However, it may be advisable to retain some navigational aids to serve as a backup during periods when the SBAS is unavailable (e.g. due to RFI).

2. Reduced Incidence of Controlled Flight into Terrain (CFIT). SBAS provides enhanced vertical guidance allowing pilots to better understand their overall orientation relative to known hazards (enhanced situational awareness). By providing geometric vertical guidance, SBAS prevents QNH error setting which could occur during APV Baro. It can also enable the introduction of Approach Procedures with Vertical guidance at airports not otherwise equipped, this enhanced situational awareness means that pilots can land safely in different weather conditions and have a better understanding of their location

with respect to the ground, reducing risks and incidents.

3. Increase in successfully completed rescue and medical flights, leading to reduced morbidity and mortality. The integrity of the signals, and the precision of vertical and horizontal positioning will allow rescue helicopters to operate in poor weather and remote locations. Emergency helicopter crews can make more accurate approaches, reach patients in challenging locations and weather conditions, and provide people with the medical treatment they need quickly.

iii. Technical Feasibility Assessment

The technical feasibility assessment should involve:

- an ionosphere threat assessment to quantify the effect of local ionospheric conditions on SBAS Integrity and Availability and whether local ionospheric conditions support the implementation of single frequency SBAS; DFMC could be one of the solutions if ionospheric conditions are such that a single frequency SBAS would not provide the required performance.
- an SBAS satellite performance assessment to assess SBAS satellite signal reception, multipath and interference;
- a desktop/simulator analysis against siting considerations to identify suitable locations where SBAS reference stations could be installed and their number; and
- Assessment of coverage and service area for the SBAS especially at the edges of the coverage and service area.

The following provides guidance in respect of various types of SBAS while performing the technical feasibility assessment as per ICAO Annex 10:

- Full SBAS implementation (Implementation Type A)

    - Satellite (transponder) deployment: SBAS satellite is usually hired from an outside agency called the satellite service provider which could be different from SBAS service provider or same. Each SBAS satellite may contain more than one navigation transponder with more than one SBAS Pseudorandom Noise (PRNs) code.
    - SBAS PRN coordination: SBAS Satellite Service provider agency should apply to US GPS PRN Coordination Office for a Pseudorandom Noise (PRN) code assignment for the SBAS satellite.
    - SBAS ID coordination: SBAS implementing agency should apply for Service Provider ID (SPID) to ICAO NSP Secretary.
    - Coverage and service volume: The SBAS coverage area corresponds to the union of transmitting satellite footprint areas. The SBAS service area is an area within the SBAS coverage where the signal performance meets the requirements for the intended operation. An SBAS system can have different service areas corresponding to different types of operation (e.g. APV-I, Category I-equivalent, etc.).
    - Service level: SBAS could be certified for various service levels like En-route, Terminal, LNAV, LNAV/VNAV, LP, LPV and CAT I-equivalent. Each service is associated with one unique value of

Horizontal and Vertical Alert Limit (HAL and VAL) and time to alert.

- Ground monitoring station siting: Ground monitoring station site is selected by conducting survey for obstruction, RF interference and multipath.
- Master station and uplink station siting: The siting criterion for Master station and uplink station should take into account the interference signal thresholds for qualifying the site.
- Robustness of communication link: Communication link is used for carrying data from reference station to master station in real-time and is crucial to ensure certified service level performance. Optical fiber and satellite link may be selected as primary and backup link to meet the Digital Communication Network (DCN) performance. The DCN should have sufficient availability, reliability, latency and redundancy to meet SBAS system performance requirements with no single point of failure.
- Maintainability aspect of the system: The SBAS system should have two types of maintenance capability i.e. Corrective & Periodic.

  - Corrective Maintenance Capability: - This capability describes the requirements for verifying anomalous conditions detected during nominal system operation, isolating faults to the LRU, supporting replacement of defective/faulty LRUs, restoring the component or equipment to full capability (including proper levels of redundancy), and performing required maintenance administration activities.
  - Periodic Maintenance Capability: - Periodic maintenance includes all mandatory activities performed on a routine or scheduled basis to maintain system performance, minimize service interruptions, and major system breakdowns, and extend the useful life of the equipment. The SBAS should be capable of supporting periodic maintenance activities without compromising either system operation or performance.

- Ionospheric impact study: Since ionospheric error is the dominant source of error in GNSS positioning, it becomes imperative to conduct study on ionosphere impact inside the service area of SBAS before deciding to provide SBAS services in that region. In general, ionospheric effects in mid-latitude regions are mild. In low-latitude regions, ionospheric effects are more severe. In high-latitude regions, ionospheric effects are more severe than in mid-latitude regions, but less severe than in low-latitude regions. In the DFMC SBAS, most of the ionospheric issues are addressed.

- Participating in existing SBAS (Implementation Type B)

  - Review of existing SBAS services: If coverage area of existing one or more SBASs is covering the area of interest of the concerned State/ANSP, then service area of the concerned SBAS may be extended by installing the SBAS reference station at the appropriate location.
  - Coordination with the SBAS provider: To install reference stations and to integrate with the existing SBAS, coordination with the concerned service provider is essential. However, each State is responsible for approving SBAS operations within its airspace. SBAS service provider will be responsible for NOTAM proposals to the appropriate Aeronautical Information Service providers of the State willing to implement SBAS based services.
  - Coverage and service volume: Same as given above for Type A scenario.
  - Service level: Same as given above for Type A scenario.

- Ground monitoring station siting: Same as given above for Type A scenario.
- Robustness of communication link, ensuring acceptable availability as a part of technical feasibility study: Same as given above for Type A scenario.
- Maintainability aspect of the system: Same as given above for Type A scenario.
- Ionospheric impact study: Same as given above for Type A scenario.

- Utilizing existing SBAS service (Implementation Type C)

  - Review of existing SBAS services: If the service area of existing one or more SBASs is covering the area of interest of the concerned ANSP, then this approach may be adapted.
  - Coordination with the SBAS provider: Same as Type B above.
  - Coverage and service volume: Same as given above for Type A scenario.
  - Service level: Same as given above for Type A scenario.
  - Available services: The State/ ANSP who desires to implement SBAS services in its region, may conduct quantitative & qualitative analysis to ascertain the coverage of APV & RNP service and subsequently and certify the service accordingly in their airspace.

iv. Concept of Operations (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. 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.

Based on the outcome of the three phases listed above i.e., Operational Need Analysis, Cost-Benefit Assessment and Technical Feasibility Assessment, a State may decide to introduce SBAS based operation at its airports. The outcome of analysis 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.

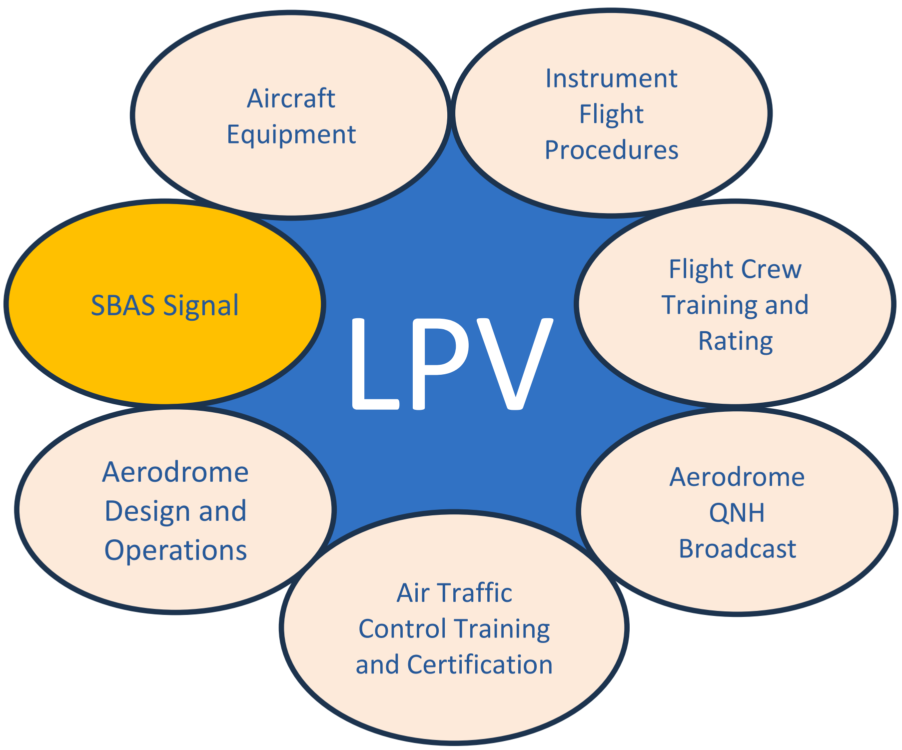
State should form an SBAS Implementation Team comprising of members from the regulatory and service provider organizations as well as user representatives including however not limited to the regulatory authority, ATC operations, aerodrome operator, airline operators, airspace management, aeronautical information services, maintenance, safety, and procedures design. Getting aircraft manufacturers in this team would also be helpful. A wide cross section of participants can provide strategic guidance and detailed recommendations on SBAS implementation.

v. SBAS Solution Selection

For those States where the use of SBAS has been determined to be beneficial, the next step is to determine which runways/airspace should be prioritized for the implementation of the SBAS procedures. The following aspects may be considered:

1. Runways, where ILS is not feasible.
2. As a back up to ILS on runways equipped with ILS.
3. Heliports for SBAS based point in space (PinS) procedure for Helicopters.
4. En-route operations, namely RNP 0.3 en-route for helicopters, where SBAS can be used without RAIM.

Typical requirement for Implementation of an SBAS(LPV/250/200) procedures



ATC Procedure Development

When deploying an 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 an SBAS:

- any changes to the information provided to pilots
- any information about predicted LPV unavailability to be provided to ATCOs
- any changes to existing documentation including any local instructions or training documentation.
- changes to ATC Human Machine Interfaces

Development of SBAS (LPV) Approach procedures:

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 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. Ground validation should be conducted to ensure that there is no significant error in the FAS DB. Flight Validation may be carried out for each instrument flight procedure either on a simulator or actual flight. This process from collecting obstacle data to publication of the procedure can take one year or more. It is suggested to appoint a national coordinator to follow up the planning of LPV procedures in one country.

Ground testing and flight test/inspection –

As per ICAO Manual on Testing of Radio Navigation Aids (Doc8071), there are two steps :

- Ground testing : Check data accuracy of FAS
- Flight test/inspection : Flight-testing/inspection of the GNSS and SBAS signals-in-space is not required. Flight test is concerned with:
  - validation of RNAV instrument flight procedures;
  - verification of adequate SBAS support for the specific procedure; and
  - testing for interference.

Since the implementation of SBAS flight procedures has already been covered in those ICAO manuals mentioned above, additional operational trial is considered non-essential. However, ANSP may consider conducting operational trial of SBAS procedures for familiarizing pilots, air traffic controllers and engineers with this relatively new technology in the APAC region.

vi. Safety Assessment

The Safety Assessment and Certification process should show that the Service provided will be acceptably safe during and after the SBAS implementation. The Safety Assessment process should 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. This Safety Case will be provided by the company who has developed the SBAS system and also by the operator of the SBAS system. Demonstration of Annex 10 performance requirements is essential.
- Service Safety. This should demonstrate that the Certified System installed within the local ATM environment will be acceptably safe.

vii. System Certification

Early engagement with the regulator on the approach to certification and the level of regulatory involvement in certification activities is critical to achieving a successful outcome. There are three stages in System Certification

- System Approval: System approval basically involves approving the design of the equipment. It spans activities ranging from Requirements Planning, System Acquisition, System Baseline, System Safety Assurance, etc.
- Facility Approval: This phase deals with the activities related to Equipment Installation & Approval of Installation. Typical activities which are part of this phase are Site Survey (RF & Multipath), Installation, conduct of SAT, Final System Integration Test, OT&E (Operational Test & Evaluation).
- Service Approval: This phase includes activities which lead to commissioning of the system. Basic activities like Aeronautical Survey, Flight Procedure Development, establishment of SBAS NOTAM system, Radio Frequency Interference Detection and Mitigation, Flight Inspection, Flight Procedure Approval, and publication of the same as per AIS process.

The key elements of the certification argument should comprise of:

- Concept Defined. Demonstration the concept of operations has been adequately defined and documented. This should address the question of how the SBAS will 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 meet legislative requirements and conforms with relevant 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 an 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 operations.

viii. Development of Regulations Related to SBAS for Aviation

Regulators, service providers and aircraft operators should all ascertain that an SBAS based operation is safe before it is introduced. This requires a systematic use of engineering and management tools to identify, analyze 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 a state's responsibility to authorize SBAS operations in its airspace and to specify any limitations on proposed operations.

It is necessary to have a collective 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 should be certified by the State's regulatory authority, where applicable. In addition, SBAS procedure(s) should not be used for civil aviation unless approved by the State's regulatory authority, where applicable.
- The flight manual covering SBAS use for various phases of flight operations should be approved by the State's regulatory authority, if applicable.
- Aircraft operators should 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 should be certified by the regulatory authority of the State.
- The SBAS service provider should carry out system checks and operational performance monitoring on a continuous basis. Reports in respect of accuracy, integrity, availability, and continuity should be prepared and shared with the regulator periodically. Any major degradation in service or breach of terms and conditions may lead to withdrawal/cancellation of certificate/approval.
- The State should also develop the approval and withdrawal process for SBAS based services/procedures.

The phased approach described below may be used for certification:

- Phase One: Pre-Application. The SBAS Operator and Maintainer or SBAS Aviation Service Providershould convene a meeting with the regulator (pre-application meeting) to ascertain 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 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 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. Reports in respect of accuracy, integrity, availability, and continuity should be prepared and shared with the regulator periodically. Any major degradation in service or breach of terms and conditions may lead to withdrawal/cancellation of certificate.

Requirement for new SBAS Service Providers

- Any new SBAS wishing to broadcast SBAS must register and obtain approval from the ITU and coordinate frequencies with other countries.
- PRN codes for SBAS satellites must be allocated in coordination with US.
- A new SBAS provider identifier must be obtained from ICAO.

ix. Training

The introduction of SBAS in any State represents a significant change for aviation, so it requires innovative 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 the States to identify the training needs for all stakeholders involved in the operation, use and maintenance of the SBAS. Stakeholders included in the analysis include ATC staff, regulatory authorities, maintenance staff, engineering staff, pilots, and procedures designers. The Training Needs analysis should:

- identify 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 some States:

- General Awareness training. General awareness involves training on the overview of GNSS and augmentation systems, principles of operation of an SBAS, differences between an ILS and SBAS based precision approach, the limitations, and advantages of an 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 an 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

an SBAS-based approach capability.

- Regulators. Regulators should be provided with general awareness training and training pertaining to applicable SARPs for updating the regulation to include SBAS operations.
- Maintenance. Staff responsible for maintaining the SBAS should be provided with training on the fundamental principles of operation of an 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 detection, resolution and analysis.
- Pilot. Pilot training will be driven by the airline and specific aircraft type. Pilot training may involve a different 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.

x. Operation Certification

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

Certification for SBAS Service Providers:

- As an SBAS service provider, the SBAS service provider should be confirmed to be in conformance with SARPs Annex 10 and should obtain approval.

Operational approval for Airlines:

- Airlines need to consult their national authority for operational approval requirements.

xi. Post-Implementation Review

Subsequent to the Commissioning of an SBAS 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 SBAS continue to be managed effectively.
- 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 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

6. Post-Implementation Activities

a. Operation and Maintenance Activities

Operation and Maintenance Activities are provided through an Operations and Maintenance Subsystem (OMSS). The Operations and Maintenance Subsystem provides an interface through which the controller/maintenance personnel access all the subsystems of SBAS for monitoring and controlling. This subsystem displays the operational status of the SBAS and also generates the event messages for various activities taking place within the system. These event messages provide information/warning/alerts, on corrective actions to be taken by maintenance personnel, if necessary. OMSS allows the maintenance personnel to configure the various subsystems in the SBAS including updating GEO and earth orientation parameters (EOP), to be used by the system.

b. Performance Indicators

States should assess the performance of the SBAS against the Performance Indicators established on a 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.

c. Promulgation of Information in AIP

The information regarding implementation of SBAS and description of SBAS based services or approaches should be promulgated in State Aeronautical Information Publication (AIP).

d. 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 SBAS, specifically on availability. Moreover, Air Navigation Service Providers (ANSP) are responsible for monitoring and reporting 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

ATC	Air Traffic Control
ATM	Air Traffic Management
ATS	Air Traffic Services
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
LRU	Line Replaceable Unit
RNAV	Area Navigation
RNP	Required Navigation Performance
SARPs	Standards and Recommended Practices
SBAS	Satellite Based Augmentation System

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Appendix 2 – References

1. *Relevant ICAO documents covering different aspects in SBAS implementation:*
   - a. *Global Strategy – Global Air Navigation Plan (Doc 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. *Doc 4444 – Air Traffic Management*
     - v. *Doc 9365 – Manual of All-Weather Operations*
     - vi. *Doc 9734 – Safety Oversight Manual*
     - vii. *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)*
   - h. *Miscellaneous*
     - i. *Presentations at GBAS/SBAS Implementation Workshop (Seoul, Republic of Korea, 3 – 5 June 2019)* (https://www.icao.int/APAC/Meetings/Pages/2019-GBAS-SBAS-.aspx)

2. *Relevant documents published by international organizations / 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 – Instrument Approach Operations

1. Approach procedure with vertical guidance (APV)

ICAO Annex 10 Volume I defines three types of instrument approach operations:

- A non-precision approach (NPA)
- An approach with vertical guidance (APV)
- A precision approach (PA)

An NPA is one where only lateral guidance is provided, it is known as a two-dimensional or 2D approach. SBAS is not required for NPA, GNSS with RAIM supports NPA.

An APV is one where aircraft navigation instruments provide a pilot with lateral and vertical guidance to enable them to fly along a defined approach path to the aerodrome. These approaches, known as 3D approaches, are safer than those where only lateral guidance is provided (NPA or 2D). While an APV is similar to a precision approach, it does not meet all the performance requirements of the latter.

Lateral guidance for an APV is provided by GNSS, while vertical guidance is typically provided by either barometric altimetry or SBAS.

A precision approach also provides lateral and vertical guidance but has more demanding requirements on the performance of the navigation system than an APV. Precision approaches have typically been provided by the instrument landing system (ILS) and GBAS. SBAS can support a precision approach – please refer to the next paragraph on LPV.

2. Localizer performance with vertical guidance (LPV)

Required navigation performance (RNP) approach charts are marked with lines of minima which, in general terms, specify how low an aircraft may descend prior to the pilot completing the landing visually if prescribed conditions are met. The lower the minima, the greater the chance of being able to use the procedure when visibility is poor.

Localizer performance with vertical guidance (LPV) is one such minima which may be shown on RNP approach charts. SBAS enables RNP approaches to LPV minima as low as 200 feet:

- when the LPV minima is at or above 200 feet but below 250 feet, it is considered a Category 1 precision approach or Type B approach
- when the LPV minima is at or above 250 feet it is categorised as an APV-I or Type A approach.

Performance requirements for instrument approach operations including APV-I and Category 1 precision approaches are provided in ICAO Annex 10. It should be noted that while requirements for APV-II are specified, this level of performance is seldom implemented.

3. Instrument approach operations

ICAO Annex 10 Volume I, Chapter 3, Table 3.7.2.4-1 specifies the signal in space performance requirements for different types of instrument approach operations. These performance requirements apply to the navigation system responsible for transmitting the signals, and can be mapped to PBN navigation specifications defined within ICAO Annex 6.

The Table below provides an example of the mapping between the different PBN Navigation specifications and the corresponding signal in space performance requirements defined within ICAO Annex 10.

In addition to the navigation system meeting the signal in space requirements, additional requirements of the flight crew and aircraft operator may be necessary to satisfy the navigation specification (refer to ICAO Annex 6).

An SBAS will support different types of instrument approach operations, including those shown in the table.

Mapping of PBN navigation specifications to navigation system signal in space requirements

SBAS Signal in Space Performance Requirements (ICAO Annex 10, Volume I, Chapter 3, Table 3.7.2.4-1)	INSTRUMENT APPROACH OPERATION				
	2D		3D		
	Type A		Type A		Type B
	LNAV (*)	LP	LNAV/VNAV (*)	LPV	LPV
Initial approach, Intermediate approach, Non-precision approach (NPA), Departure	X		X (Lateral)		
Approach operations with vertical guidance (APV-I)		X (Lateral)	X (Vertical)	X	
Category I Precision Approach					X

Notes:

1. 2D instrument approach operations use lateral navigation guidance only whereas 3D instrument approach operations use both lateral and vertical navigation guidance;

2. A Type A operation is one with a minimum descent height or decision height at or above 250 feet, and a Type B operation is one with a minimum descent height or decision height below 250 feet;
3. to support an instrument approach operation to LNAV minima, the SBAS signal in space must meet the performance requirements for a Non-Precision Approach as detailed in Chapter 3, Table 3.7.2.4-1 of ICAO Annex 10, Volume I;
4. to support an instrument approach operation to LP minima, the SBAS signal in space must meet the lateral performance requirements for APV-I as detailed in Chapter 3, Table 3.7.2.4-1 of ICAO Annex 10, Volume I;
5. to support an instrument approach operation to LNAV/VNAV minima, the SBAS signal in space must meet the lateral performance requirements for a Non-Precision Approach and vertical performance requirements for APV-I as detailed in Chapter 3, Table 3.7.2.4-1 of ICAO Annex 10, Volume I;
6. to support an instrument approach operation to LPV minima of 250 feet or greater (Type A), the SBAS signal in space must meet the lateral and vertical performance requirements for APV-I as detailed in Chapter 3, Table 3.7.2.4-1 of ICAO Annex 10, Volume I; and
7. to support an instrument approach operation to LPV minima of lower than 250 feet (Type B), the SBAS signal in space must meet the lateral and vertical performance requirements for Category I as detailed in Chapter 3, Table 3.7.2.4-1 of ICAO Annex 10, Volume I. Table 3.7.2.2-1 provides a range of values for the Vertical Protection Level (VPL) from 10 to 35 metres. Additional safety analysis is required if a VPL of greater than 10 metres is used. Further guidance material on using a VPL of greater than 10 metres is available in Attachment D of ICAO Annex 10, Volume I.

Appendix 4 – Experience Sharing by States/Administrations

(a) GAGAN – Indian SBAS

Satellite Based Augmentation (SBAS)
-GAGAN in India

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);
III. Galileo that provides a single- and dual-frequency Open Service (OS);
IV. BeiDou Navigation Satellite System (BDS) that provides the BDS Open Service (BDS OS);
V. Aircraft-based augmentation system (ABAS);
VI. Satellite-based augmentation system (SBAS)
VII. Ground-based augmentation system (GBAS);
VIII. Ground-based regional augmentation system (GRAS)
IX. 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, GLONASS, Galileo & BDS), ABAS, GBAS, SBAS, GRAS 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 ICAO Annex 10, four core satellite constellations have Standards and Recommended Practices (SARPs) incorporated: the GPS from United States of America, GLONASS from the Russian Federation, Galileo from European Union and BDS from China.

The core constellations have the capability to provide accurate position and time information worldwide. The accuracy provided by these 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, SBAS GBAS & GRAS.

2.3.1. 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.

2.4. 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 neighboring 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.

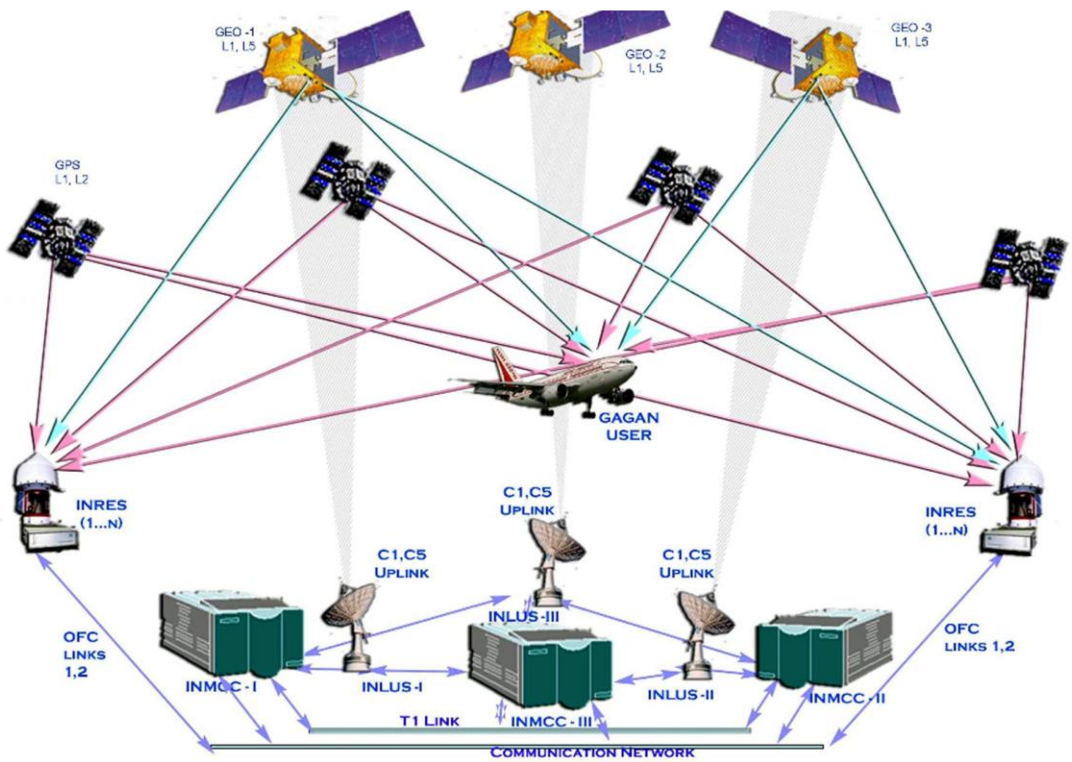
GAGAN provides augmented information for the GPS signals to enhance the accuracy and reliability of position estimates.

Airports Authority of India (AAI) in collaboration with Indian Space Research Organisation (ISRO) has developed the Indian SBAS called GPS Aided GEO Augmented Navigation (GAGAN) System to improve the accuracy, integrity and availability of GPS signals. GAGAN allows use of GPS as the aviation navigation system, from take-off through APV-I approach. GAGAN is a critical component of the AAI's strategic plan to establish a seamless satellite navigation system for civil aviation for enhancing capacity and safety. GAGAN provides a civil aeronautical navigation signal consistent with International Civil Aviation Organization (ICAO) Standards and Recommended Practices (SARPs) as established by the Global Navigation Satellite System (GNSS) Panel.

The GNSS satellites' data is received and processed at widely dispersed Indian Reference Stations (INRESs), which are strategically located to provide coverage over the required service volume. Data is forwarded to the Indian Master Control Center (INMCC), which processes the data from multiple INRESs to determine the differential corrections and residual errors for each monitored satellite and for each predetermined Ionospheric Grid Point (IGP). Information from the INMCC is sent to the Indian Land Uplink Station (INLUS) and uplinked along with the Geostationary Earth Orbit (GEO) navigation message to the GAGAN GEO satellite. The GAGAN GEO satellite downlinks this data via two L-band signal frequencies (L1 and L5), with Global Positioning System (GPS) type modulation. The INRES, INMCC, and INLUS communicate via a Data Communication Subsystem (DCSS).

The GAGAN system is a safety-critical system consisting of the equipment and software that augments the GPS SPS. The GAGAN system provides a Signal-In-Space (SIS) to GAGAN Users to support RNP 0.1 and APV-I phases of flight. GAGAN users include all aircraft with approved SBAS avionics using the GAGAN SIS for any approved phase of flight.

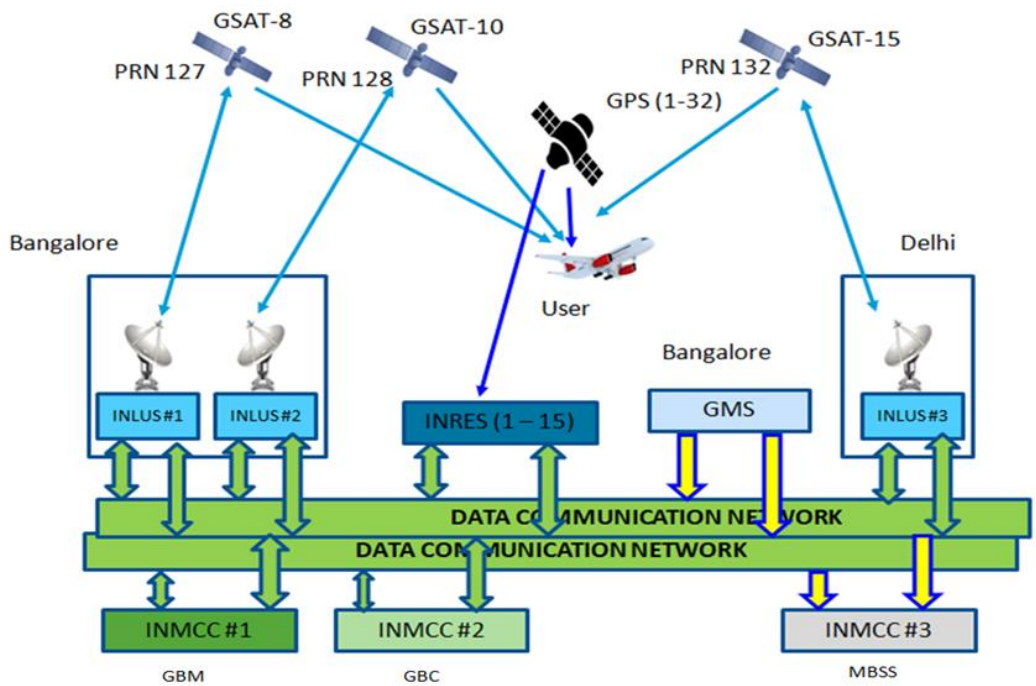
GAGAN system's architecture has two segments, one is ground segment and the other is space segment. At present the ground segment consists of 15 reference stations spread all over India and two master control centres and one MBSS (Minimal Basic Shadow System – INMCC-III). These 15 reference stations 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 by redundant terrestrial networks. 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.



2.4.1. Certified GAGAN SIS Performance

GAGAN has been certified for two types of operations i.e., RNP 0.1 & Approach operations with vertical guidance (APV-I).

GAGAN's RNP 0.1 service has the following characteristics:

Parameter	Value
Horizontal Accuracy (95%)	72m
Vertical Accuracy (95%)	N/A
Integrity (per hour)	$1\text{-}1\text{x}10^{-7}$
Time-to-alert	10s
Continuity (per hour)	$1\text{-}1\text{x}10^{-4}$
Availability over Indian FIR	>99%
Vertical Alert Limit	N/A
Horizontal Alert Limit (185.2m = 0.1NM)	185.2m

GAGAN's APV-I/ service has the following characteristics:

Parameter	Value
Horizontal Accuracy (95%)	7.6m
Vertical Accuracy (95%)	7.6m
Integrity (per approach)	$1\text{-}2\text{x}10^{-7}$
Time-to-alert	6.2s
Continuity (over any 15 seconds)	$1\text{-}8\times10^{-6}$
Availability over 76% of the Indian land mass excluding the period of solar storms on nominal days	99%
Vertical Alert Limit	50m
Horizontal Alert Limit	40m

On stormy days, APV-I/ service will be degraded.

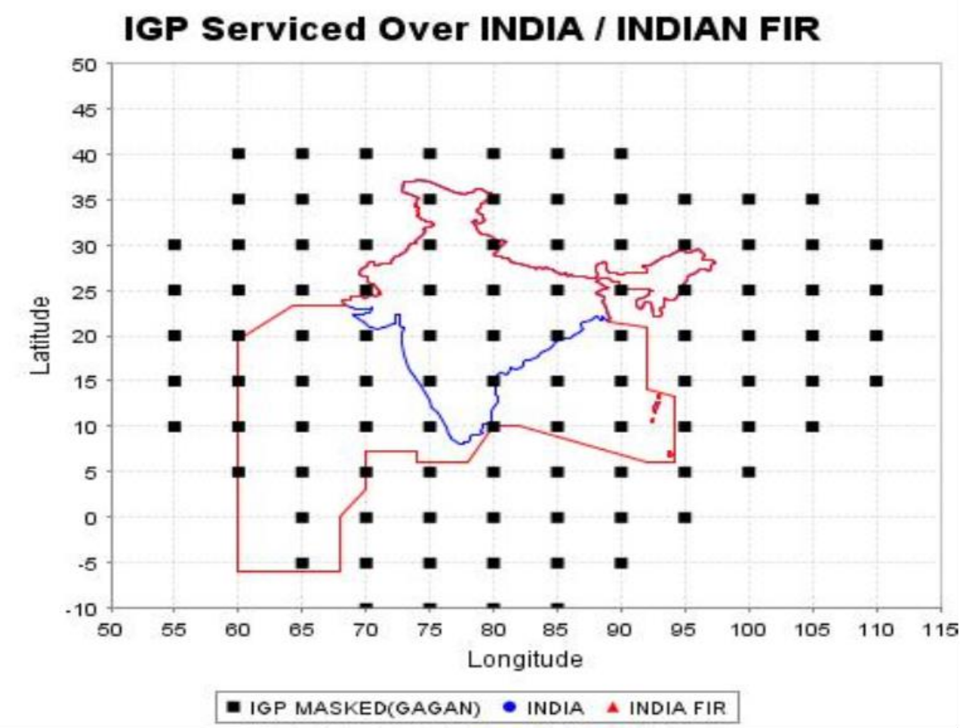
When measuring the APV-I performance parameters, the following rules apply:

1. Epochs (the entire period for all of India) which experience solar storms do not count against the availability requirement.
2. Nominal days are defined as days when the max chi^2 statistic is less than 3.
3. Solar storms are defined to be present when the GAGAN storm detector trips.

Actual Horizontal as well as Vertical position accuracy (95%) of GAGAN is better (around 1-2 meters) than certified accuracy.

2.4.2. IGPs Serviced by GAGAN

Ionospheric corrections are being provided for total 102 IGPs by GAGAN distributed across three Ionospheric Mask Bands i.e., 5, 6 & 7. Figure below shows the IGPs served by GAGAN over Indian FIR region.



2.5. DGCA Certification of GAGAN

Ionospheric corrections are being provided for total 102 IGPs by GAGAN distributed across three Ionospheric Mask Bands i.e., 5, 6 & 7. Figure below shows the IGPs served by GAGAN over Indian FIR region.

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.

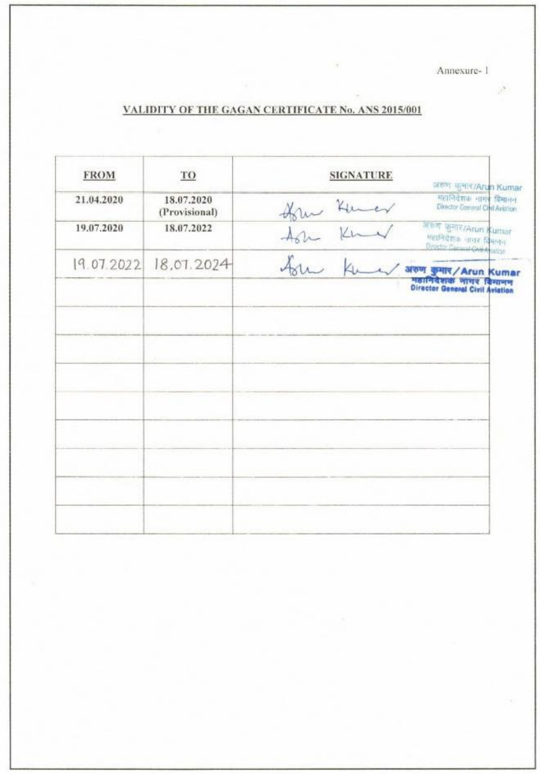
The certificate is liable to be suspended/ modified/ withdrawn or subject to any limitations or conditions, if any violation of the provisions of the Aircraft Act 1934 & the Aircraft Rules 1937, or any order/ direction/ requirements issued under the said Act/ Rules is observed.

This certificate is non-transferable.

Place : New Delhi

Date of Issue: 21.04.2015

Director General Civil Aviation



Annexure- 1

VALIDITY OF THE GAGAN CERTIFICATE No. ANS 2015/001

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

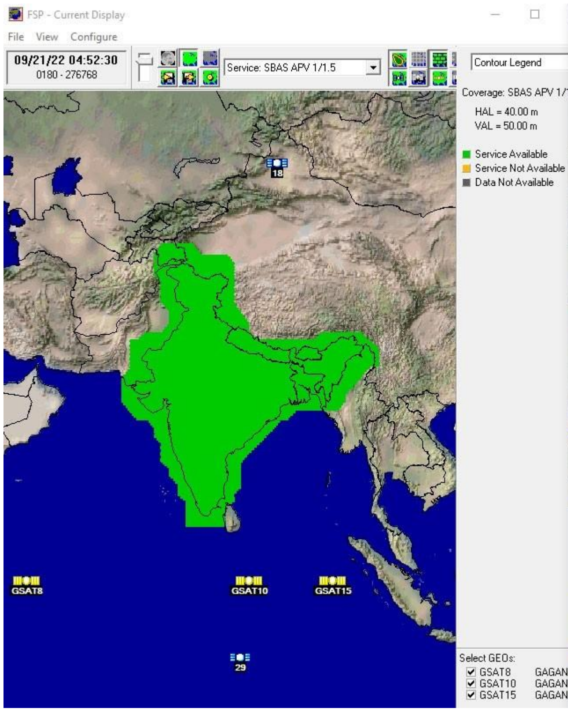
The details on GAGAN system are published in *ENR 4.3 – GLOBAL NAVIGATION SATELLITE SYSTEMS (GNSS)* of e-AIP India.

ENR 4.3 Global Navigation Satellite System (GNSS)			
Name of GNSS element	Frequency	Coordinates Nominal SVC area Coverage area	Remarks
GAGAN	L1=1575.42 MHz L5=1176.45 MHz	RNP 0.1: 99% of time over 100% of Indian FIR APV 1: 99% of time over 76% of Indian Landmass	Subject to availability of at least one GAGAN GEO Satellite

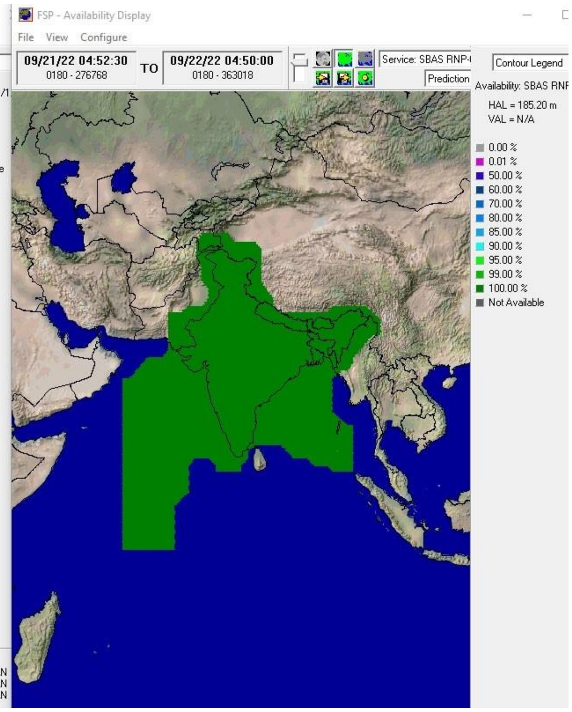
2.6. GAGAN Performance

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



2.7. 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 DO-229 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.

2.8. 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 with latest survey reports and Obstacle & Terrain data.

2.8.1. 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 should consider that:

a) All obstacles be accounted for. Items, such as trees and heights of tall buildings should be accounted for either by physical examination of the site or by addition of a suitable marginabove 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.

2.8.2. 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.

2.8.3. 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.

2.8.4. 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.

2.8.5. 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 conveys approval for each procedure in writing.

2.8.6. 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:

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

2.8.7. LPV procedure development in India

A total of 53 ICAO SBAS channel numbers for LPV procedures have been assigned to India as on May 2025.

a) AAI has published Twenty-three (23) LPV procedures for fifteen airports in India as on date.

b) AAI has developed Twelve (12) more LPV procedures for various airports in India. Simulator validation and flight trials of these procedures are in progress.

c) Eighteen (18) LPV Procedures are under design & development phase.

d) The published LPV procedures are available on the following link (Please select the applicable Aerodrome from AD_2 under section PART 3 - AERODROMES):
https://aim-india.aai.aero/eaip-v2-02-2025/index-en-GB.html

e) Additionally, list of published and planned LPV in India can also be seen on the following ICAO APAC web-link:
https://www.icao.int/APAC/Pages/GBAS-SBAS-MAP.aspx

AAI has also upgraded its Flight Inspection Unit aircraft for GAGAN LPV procedures validation and same has been certified by DGCA, India.