*International Civil Aviation Organization*

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

*(Bangkok, 7- 9 May 2024)*

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

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

# POINTS OF DISCUSSION ON SBAS IMPLEMENTATION GUIDANCE

(Presented by Co-Chairs)

**SUMMARY**

This paper presents summarizes the points of discussion on the SBAS implementation guidance document. States/Administrations are invited to review the draft and provide inputs under points of discussion or any other comments on the draft SBAS implementation guidance document.

## 1. INTRODUCTION

1.1 The 3rd meeting of the GBAS/SBAS Implementation Task Force (GBAS/SBAS ITF/3) decided to establish an expert group (Expert Group 3-2) to develop guidance documents for implementation of SBAS and GBAS in the Asia/Pacific Region.

1.2 Since the last meeting of the Task Force (GBAS/SBAS ITF/5) held in June 2023, the draft guidance documents on SBAS has been uploaded to the ICAO share point for the review and edit by the Expert Group members. The Expert Group also met online three times (11 September, 17 October, and 5 December 2023) to discuss proposed modifications and address comments raised.

1.3 However, the Expert Group could not finish considering and addressing all the modifications and comments. The draft SBAS implementation guidance document has not been matured yet, and still needs further revision. This working paper summarizes the points of discussion on the SBAS implementation guidance documents.

## 2. DISCUSSION

2.1 The SBAS implementation guidance document is being developed by following the structure of the GBAS implementation guidance document which is considered to be more matured. However, the structure should also be adjusted appropriately to align with the characteristics of SBAS implementation.

2.2 Specific points for further discussion and consolidation are summarized in Table 1. The current draft guidance document can be found as Attachment to this Working Paper.

***Table 1 - Points of Discussion for Each Section***

| **Section** | **Status, Suggestions, Comments** | **Actions** |
| --- | --- | --- |
| 1. Objectives and Scope of the Guidance Document | It is suggested to include terminal and en-route operations.<br>- Resolution has been proposed. | Should be reviewed for finalization. |
| 2. Executive summary | Executive summary has been provided. | Should be revisited for finalization as the main body of the guidance documents is finalized. |
| 3. Roles and Responsibilities of Stakeholders | It is suggested to list out the stakeholders.<br>- Resolution has been proposed.<br>Who should conduct cost-benefit analysis (CBA) may need to be added (in relation to 5.a.ii). | Review if the comment has been addressed.<br>Consider the comment on CBA to address it. |
| 4. Performance Indicator | Performance indicators of SBAS are introduced and examples of them are listed out. | Should be reviewed for finalization. |
| 5. Implementation Process for SBAS | (Title only) | - |
| a. Overview | Space, ground and airborne segments of SBAS has been explained.<br>Changes and comments have been provided. | Should be reviewed if all the comments have been addressed. |
| b. Framework, Phases and Elements of SBAS Implementation Process | (Title only) | - |
| i. Operational Need Analysis | Operational need analysis is extensively explained.<br>Some modifications have been proposed.<br>A question on the need of this paragraph has been raised. | Should be considered if this paragraph is necessary.<br>Review the contents if agreed to retain this paragraph. |
| ii. Cost-Benefit Assessment | Cost-benefit assessment (CBA) is extensively explained.<br>Who should conduct CBA should be clarified (in connection with Section 3).<br>More details and deliberation on assessment for the three types of SBAS implementation are required. | Should be revised to address all the comments. |
| iii. Technical feasibility Assessment | Technical feasibility assessment is extensively discussed based on inputs from India.<br>Additional items proposed to be included. | Should be reviewed if all the comments have been addressed.<br>Should be reviewed with experiences by States/Administrations. |
| iv. Concept of Operations (CONOPS) Development | Developing CONOPS for SBAS is explained.<br>Proposed to describe about SBAS | Proposed amendment should be reviewed for agreement. |

| **Section** | **Status, Suggestions, Comments** | **Actions** |
|---|---|---|
| | implementation team. | |
| v. SBAS Solution Selection | Considerations necessary to determine appropriate SBAS solution is needed.<br>Comments to reconsider/add items are provided, and they are still open. | Should be revised to address all the comments. |
| vi. SBAS Flight Procedure Development | Principles and LPV procedure design are explained.<br>Reference to ANSPs and Flight Procedure office is proposed.<br>Flight validation aspects are proposed to be included. | Should be reviewed if all the comments have been addressed.<br>Should be reviewed with experiences by States/Administrations. |
| vii. Flight Check | This section has been proposed to be removed.<br>Flight validation aspects have been included in vi. | Need of this section should be discussed. |
| viii. Safety Assessment | The safety assessment aspect has been discussed with reference to system and service safety aspects. | Should be reviewed if all the comments have been addressed.<br>Should be reviewed with experiences by States/Administrations. |
| ix. System Certification | System/Facility/Service Approvals have been described.<br>Several comments/amendments have been provided and resolutions have been proposed. | Should be reviewed if all the comments have been addressed.<br>Should be reviewed with experiences by States/Administrations. |
| x. Development of Regulations Related to GBAS for Aviation | Regulatory basis and those specific to SBAS are provided.<br>Several comments/amendments have been provided and resolutions have been proposed. | Should be reviewed if all the comments have been addressed.<br>Should be reviewed with experiences by States/Administrations. |
| xi. Training | A section with 8 bullet items are proposed. | Should be reviewed with experiences by States/Administrations. |
| xii. Operational Certification | Clarification to “approval for operation”. | Clarification needed. |
| xii. Post-implementation Review | Two points are suggested to pre-implementation review. | Should be reviewed with experiences by States/Administrations. |
| 6. Post Implementation Activities | A good amount of contents has been provided by India. | Should be reviewed based on experiences by other States/Administrations for finalization. |
| Appendix 1. Terminology and Definitions | Abbreviations have been listed out. | More terms should be added as necessary. |
| Appendix 2. Reference Documents | Relevant documents by ICAO and RTCA have been listed out. | Should be reviewed for finalization. |
| Appendix 3. Experience sharing by States/Administrations. | An extensive but only one chapter by India on implementation of GAGAN by India. | Should be reviewed, and more experience sharing by other States/Administrations is desirable. |

2.3 The high-level timeline in completing remaining works for preparing the guidance document for implementation of SBAS is proposed in Appendix A for members' consideration.

## 3. ACTION REQUIRED BY THE MEETING

3.1 The meeting is invited to:

a) review and note the status of development of the SBAS implementation guidance document;
b) consider the way forward to revise and finalize the guidance document with the proposed timeline in Appendix A;
c) urge States/Administrations to contribute to the guidance document development through the Expert Group; and
d) discuss any relevant matters as appropriate.

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**Appendix A – Timeline in completing remaining works for preparing the guidance document for implementation of SBAS**

| **Period** | **Activities** | **Outcomes** |
|---|---|---|
| **May – August 2024** | States sharing with Expert Group their further inputs and comments on the draft SBAS implementation guidance document<br><br>***(Action: States/Administrations)*** | States' relevant contribution for revising the draft SBAS guidance document |
| **September – October 2024** | Review the consolidated inputs from States and prepare a revised revision of draft SBAS implementation guidance document to incorporate/address them<br><br>***(Action: Expert Group Members, Leads/Co-Lead, and Co-Chairs)*** | Preparing revised revision via circulation by emails |
| **End October 2024** | Expert Group Member Meeting with Chair (online Web Meeting)<br><br>***(Action: Leads/Co-Lead and Chair)*** | Conclude a new revision of draft SBAS implementation guidance document for States' further comments, and identify any outstanding section(s) requiring further inputs from States |
| **November – December 2024** | Circulate the new revision to collect further inputs from States<br><br>***(Action: States/Administrations)*** | Further inputs from States |
| **January 2025** | Revise the draft SBAS implementation guidance document to incorporate further inputs from States<br><br>***(Action: Leads/Co-Lead and Chair)*** | Another revision of draft SBAS guidance document |
| **February – March 2025** | Conduct online meetings to further discuss the revision and comments consolidate with Expert Group Members and States' delegates<br><br>***(Action: States/Administrations, Expert Group Members, and Co-Chairs)*** | A final draft for review in APAC GBAS/SBAS ITF/7 |
| **APAC GBAS/SBAS ITF/7** | Presenting the final draft of guidance reference document for implementation of SBAS in the Asia/Pacific Region in APAC GBAS/SBAS ITF/7 for endorsement<br><br>***(Action: Co-Chairs)*** | Finalize the 1st issue of guidance reference document for implementation of SBAS in the Asia/Pacific Region |

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Attachment B

**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 implementation of determination of the requirement for a Satellite Based Augmentation System (SBAS) to support APV/precision approaches (LPV minima) at an airport or several airports in a continent or region. specific airports. and some terminal and enroute operations.

[New Zealand: Propose to include terminal and enroute operations in order not to contradict Section 5a below]

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# 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 geometric vertical guidance, independently of QNH and temperature precision approach capability, and with a Decision Height of 250ft, and maybe down to 200ft.. It could replace ILS Cat I at regional airports and complement ILS at international airports in case of outages.

# 3. ROLES AND RESPONSBILITIES OF STAKEHOLDERS

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

[New Zealand: Propose to list out the stakeholders and their roles as much as possible]

- SBAS Service Provider
- ANSP
- Regulator
- Air space Users
- Aerodrome Operators
- Flight Procedure Design Organization

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# 4. PERFORMANCE INDICATORS

Performance indicators are quantifiable indicators got by measurements/statistics to showthe performance or progress towards the intended result(s). Each state should consider

Formatted: Normal, Indent: Left: 0", Right: 0" establishing a set of performance indicators against which the performance of SBAS is evaluated. Examples of performance indicators established by states in the region include:

- Availability of Signal in Space (SIS)
- Integrity and accuracy of Signal in Space (SIS)
- Availability of SBAS based navigation services (Precision/Non-precision)
- Continuity of SBAS based navigation services (Precision/Non-precision)
- Status of Ground equipment such as Reference Station, Uplink Station, Mission Control Centre etc.
- Operational Availability of the SBAS
- Number of SBAS approaches performed into the aerodrome
- Operation and Maintenance costs
- Enhancement in airport access/capacity
- Fuel saving and environmental ~~performance~~ benefit
- ~~Optimization of ATC procedures and reduction of workload~~

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~~[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 several aspects with benefits from ~~G~~SBAS 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~~ to States when implementing SBAS, ~~and~~ certifying a

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

The SBAS is a Global Navigation Satellite System (GNSS) based airspace navigation system, intended to support~~ing~~ enroute, ~~to~~ terminal airspace operations, consisting of the geostationary satellites 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 GNSS ~~GPS or other core~~ satellite constellation and geostationary satellites. ~~which~~ The core satellite constellation provides ~~the ranging signals and orbital parameters~~ the position and time information worldwide, using precise range measurements from satellites. Both SBAS ground facility and airborne ~~systems~~ components get their positions and time from the constellation ~~use ranging signals~~. The ~~space segment also consists of~~ geostationary satellites provide ranging, integrity and correction information which augments core satellite constellation signals ~~relay SBAS signals generated by the Ground Segment to Airborne Segment~~. The transponders on-board geostationary satellites broadcast the SBAS messages (i.e. differential corrections).
- [New Zealand: Other constellations can also provide signals to SBAS and with the adoption of Amendment 93 to ICAO Annex 10, Volume 1 on 2 November, enabling DFMC Galileo, BDS, GOS, GLONASS, etc, can all be used. Propose to amend 'GPS satellite constellation' with 'core GNSS satellite constellations'.]

- Ground Segment. The ground segment consists of:
  - a network of ground reference stations that monitor satellite signals on a vast area, a region or a continent;
  - master stations that collect and process ground reference station data and generate SBAS correction messages; and
  - uplink stations that send the correction 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; and
  - optional ranging parameters to provide additional ranging signals.

An SBAS based approach procedure does not require any SBAS infrastructure at an airport.

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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 collect and process the data from the ground reference stations to generate range corrections for each GNSS satellite, together with estimates of the residual errors after these corrections are applied, and integrity parameters. This information is sent to satellite uplink stations for transmission to geostationary 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 geostationary (SBAS) satellites which relay information generated by the Master stations to airborne receivers.

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

Airborne Segment
SBAS capable GNSS receivers on aircraft process the signals from the GNSS satellites and apply the corrections broadcast by the SBAS geostationary 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 can be supported.

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

In addition to processing the GNSS signals, an SBAS capab ...

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- Airborne Segment. The airborne segment consists of SBAS receiver on the on-board aircraft. The SBAS receiver applies the corrections to satellite ranging signals broadcast by the SBAS geostationary satellites 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. A simple GPS receiver is not sufficient to process SBAS messages.

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## b. Framework, Phases and Elements of SBAS Implementation Process

### i. Operational Need Analysis

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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~~ implement SBAS. The analysis should involvea thorough examination of:

- ~~current~~ existing navigation capability within the airspace including objectives, ~~measures~~ measurementsof effectiveness, operational policies and constraints, ~~current~~ existing 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 way of design of SBAS procedures ~~will be designed~~ including whether the procedures intend to overlay existing approach procedures ~~(ILS or RNAV look alike) into~~ at theairport or are new procedures in their entirety;

[New Zealand: Propose to change RNAV above to RNP as 'RNP' is now the new 'RNAV' for approaches]

- how the implementation of a SBAS aligns with the overarching navigation strategy for the state;
- industry desire for a SBAS installation;
- ~~what~~ the level of performance/service, proposed to be achieved by SBAS ~~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 way of proposed SBAS ~~is intended to be used~~ usage within the operational environment;
- the different modes of operation for the SBAS;
- ~~what~~ the level of SBAS status monitoring ~~should~~ to be provided to both ~~ATC~~ ATS units and maintenance centres;
- what the envisaged technical support environment could look like including

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- different types of operational uses and expected responses under each use case;
- the effect on staff requirement with implementing a SBAS and any new capabilities that may need be required 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

[New Zealand: A comment on whether do we need to identify who should conduct the CBA and include this under Section 3 'Role and Responsibility of Stakeholder']

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

- Full SBAS implementation (Implementation Type A)
- Participating in existing SBAS system (Implementation Type B). This means that adding ground reference stations could help to improve the service coverage. Simulations of the service coverage should be launched with the existing SBAS system to appreciate the possibilities of extension of service coverage.
- Utilizing existing SBAS service (Implementation Type C). Taking advantage of the service coverage above a State, agreement between the owner of the SBAS system and this State could permit service in this State.

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

In parallel with the development of the Concept of Operations, a cost benefit assessment should be performed to understand 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,

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- 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.
- Identification of other non-aviation uses of SBAS and community benefits from the SBAS implementation.

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

- SBAS does not require any ground installation at the airport and thus can increase runway throughput compared to the equivalent category of ILS.
- ILS localizer and glide path antenna arrays are placed adjacent to the runway. In contrast, SBAS does not require any ground installation at the airport, thereby reducing the risk of aircraft and localiser damage in overrun situations or aircraft and glide path damage in case of runway excursions~~s~~.
- SBAS can reduce controlled flight into terrain (CFIT), flight delays or diversions at airports which cannot install ILS on all runway ends because of terrain or other challenges.
- SBAS can reduce system support and maintenance cost in the long term, including simpler, less frequent flight inspections, compared to ILS.
- SBAS can provide stable and consistent approach with no vertical guidance fluctuations.
- If there is a need to displace the threshold, SBAS can support the new approach based on new threshold.
- SBAS can support several approach glide angles to the same runway that may allow setting approaches at different glide angles that best fit different kind of aircraft operating at the airport.
- More precise navigation offered by SBAS in the terminal area may provide an opportunity to greatly reduce the impact of aviation related noise by restricting aircraft to defined three dimensional routes designed to reduce the noise effects. Hence, the current costs associated with noise mitigation and noise abatement may be reduced.

New Zealand Cost Benefit Study to Implement SBAS

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There are three main benefit areas:

1. Increased network reliability – reduction of operating and passenger costs associated with delays, diversions, and cancellations (DDC). Reductions in decision heights across several airports and using these assumptions have estimated at least some reduction in decision-height for 33 of the 46 New Zealand airports that are under consideration. The ability to land in a greater range of conditions – particularly where cloud cover is low or visibility is compromised – will allow for a reduction in delays, diversions, and cancellations with attendant benefits to aircraft operation costs and passenger time lost.
   - Ø The increased operations to existing controlled and uncontrolled aerodromes in New Zealand from SBAS enabled lower approach minima.
   - Ø Enabling improved access to aerodromes that do not have instrument approach procedures, but using SBAS enabled LPV procedures
   - Ø The safety impact of SBAS enabled LPV procedures at controlled aerodromes in New Zealand (i.e. safety improvement, assets not destroyed or damaged and any residual benefits e.g. lower insurance costs).
   - Ø Ground based real time integrity monitoring at aerodrome locations which can be used for many applications including post incident analysis.
   - Ø Enhancement of performance-based navigation operations resulting from RAIM prediction not being required.
   - Ø Many airports will get results that would normally require high-cost infrastructure.
   - Ø Reduced cost of maintaining terrestrial radio navigation aids.
   - Ø Possible benefits to unmanned aerial vehicle/remotely piloted aircraft system operations.

2. Reduced Incidence of Controlled Flight Into Terrain (CFIT). SBAS provides for enhanced vertical positioning allowing pilots to better understand their overall orientation relative to known hazards (enhanced situational awareness). It can also enable the introduction of Approach Procedures with Vertical guidance at airports not otherwise equipped, and on aircraft that lack specialist (e.g. Baro-VNAV) technology. 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.
   - Ø Provide the potential for approaches with vertical guidance at almost all airports in New Zealand. Currently only controlled airports tend to have vertical guidance and some aircraft are not equipped for a lot of the approaches with vertical guidance.
   - Ø More efficient use of airspace.
   - Ø Improved navigation performance (accuracy, availability and integrity) and improved safety benefit through significant gains in pilot situational awareness and less intense workload and operating techniques as a result of incorporating a stabilised descent rather than the stepped 'dive and drive' descent profiles historically utilised with laterally guided approaches.

3. Increase in successfully completed rescue and medical flights, leading to reduced morbidity and

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~~1.~~ Human cost of lives saved from successful helicopter operations to hospital helipads and for rescue operations in poor weather conditions

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~~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)~~

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

- Utilizing existing SBAS service (Implementation Type C): This approach should be most preferred as it incurs minimum cost to implement.
- Participating in existing SBAS (Implementation Type B): If service area of existing SBAS is not covering the ANSP's area of responsibility then this should be next preferred approach by establishing additional reference stations of concerned SBAS.
- Full SBAS implementation (Implementation Type A): This is the last option if none of the above approaches work.

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

### iii. Technical Feasibility Assessment

As part of the planning process, it is important to consider whether SBAS implementation is technically feasible in the State.

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.
- 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
- Assessment of coverage and service area for the SBAS.

~~As part of the planning process, it is important to consider whether SBAS implementation is technically feasible in the State.~~

~~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 SBAS;~~
- an SBAS satellite performance assessment to assess SBAS satellite signal reception, multipath and interference;
- a desktop/simulator analysis against siting considerations to identify

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suitable locations where SBAS reference stations could be installed; and

- Assessment of coverage and service area for the SBAS.

The following provides guidance in respect of various types of SBAS while performing the technical feasibility assessment:

- Full SBAS implementation (Type A)
    - Satellite (transponder) deployment: SBAS satellite is usually hired from outside agency called the satellite service provider which could be different from SBAS service provider or same. SBAS satellites could have GEO stationary orbit or GEO synchronous orbit (slightly inclined). Each GEO satellite may contain more than one navigation transponder with more than one SBAS Pseudorandom Noise (PRNs).
    - SBAS PRN coordination: GEO Satellite Service provider agency should apply to US GPS PRN Coordination Office for a Pseudorandom Noise (PRN) code assignment for the SBAS GEO.
        - 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, etc.).
    - Service level: SBAS could be certified for various service levels like En-route, Terminal, LNAV, LNAV/VNAV, LP, LPV & CAT I. Each service is associated with one unique value of Horizontal and Vertical Alert Limit (HAL & VAL).
    - Ground monitoring station siting: Ground monitoring station site is selected by first conducting preliminary site survey to shortlist viable sites in terms of space, infrastructure availability, etc. Later, primarily, three types of surveys are conducted at each of the sites identified above i.e. Obstruction survey, RF Interference survey & Multipath survey. Based on the results of these surveys, an engineering decision is taken for zeroing on one most suitable site.
    - Master station and uplink station siting: The siting criterion for Master station and uplink station are similar to the criterion of Ground monitoring station siting except for the interference signal thresholds for qualifying the site.
- Robustness of communication link, ensuring acceptable availability as a part of technical feasibility study: Communication link which are mainly used for carrying data from reference station to master station in real-time, are very crucial to ensure meeting of certified service level performance. Optical fiber and satellite link may be selected as primary and backup link for meeting the typical characteristic & baseline requirement for Communication link or 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. The Communication link should have redundant paths, probably

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**Formatted:** List Paragraph, Justified, Bulleted + Level: 1 + Aligned at: 0.25" + Indent at: 0.5" one through terrestrial & another through satellite link. Latency is important factor in maintaining TTA requirement. Latency for the DCN is defined as the time to traverse the communication circuits between facility demarcation points including processing, queuing, transmission/retransmission, connecting, and propagation delays. It should be small enough to cater real time processing requirement of an SBAS system.

- 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 shall be capable of supporting periodic maintenance activities without compromising either system operation or performance.

- Ionospheric impact study: Since, ionospheric error is 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.

The behavior of the ionosphere, as far as its observable effects on radio signals are concerned, varies with time and location. Since the ionization of the upper atmosphere (i.e., the ionosphere) is caused by radiations from the Sun, the density and altitude distribution of the free electrons it contains vary with the 11-year solar cycle, the season of the year, and time of day. They also vary as a function of geomagnetic latitude. Finally, they can be severely perturbed by rare geomagnetic (ionospheric) storms caused by powerful energetic emissions from the Sun.

In general, ionospheric effects in mid-latitude regions are mild: variations in ionospheric delays are gradual and scintillation virtually inexistent. This may not be true during severe ionospheric (geomagnetic) storms, but such storms are very rare, and their effects can be detected, and sometimes corrected, by augmentation systems. In low-latitude regions, ionospheric effects are more severe: large variations ionospheric delays and patches causing intense amplitude and phase scintillation are frequent, particularly during the local evening hours during years near a peak of the solar cycle. Furthermore, steep ionospheric delay gradients can occur at the edges of deep ionospheric depletions, also known as ionospheric bubbles. In high-latitude regions, ionospheric effects are more severe than in mid-latitude regions, but less severe than in low-latitude regions. This is due to the magnitudes of ionospheric delays, which, while fairly variable, tend to be much smaller than in low-latitude regions. Scintillation can also occur in high-latitude regions, particularly during periods of increased ionospheric activity. It mostly occurs in the form of phase scintillation

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To conduct above study, both real & simulated Iono data should be collected for multiple days. These days should be sufficient enough to cover data from both nominal & stormy ionospheric conditions, peak of 11-year solar cycle, equinox months, depletion and scintillation. Based on above study, ionosphere should be characterized for the region hence culminating in region specific Iono model. For this purpose, existing ionospheric model could also be used subject to clearances from the concerned agency who developed this model. For more details regarding iono model development, etc., please refer to *SBAS Iono Safety Assessment Guidance Document* published by ICAO APAC regional office.

-

- 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 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 station and integrating with the existing SBAS, coordination with the concerned service provider is essential. Also, to issue channel number for the particular LPV flight procedure at an airport of the concerned State, approval of the SBAS service provider is required. However, each State is responsible for approving SBAS-based operations within its airspace. Information about Coverage area of an SBAS may be sought from respective service provider agency whereas service area of the SBAS may be obtained either from MT 27 message (if that SBAS broadcasts it as per ICAO Annex 10.) or may be asked from respective service provider agency. SBAS service provider will be responsible for Notice To Airmen (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 (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: To issue channel number for

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- 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 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, certify the service accordingly in their airspace.

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- 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

[New Zealand: Propose to include aircraft fleet capability]

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[New Zealand: Propose to include aerodrome infrastructure capabilities and potential benefits to aerodrome approach operations over a non-SBAS environment]

- 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~~

[New Zealand: Propose to include aircraft fleet capability]

[New Zealand: Propose to include aerodrome infrastructure capabilities and potential benefits to aerodrome approach operations over a non-SBAS environment]

- ~~Utilizing existing SBAS service (Type C)~~
  - ~~Review of existing SBAS services~~
  - ~~Coordination with the SAS provider~~
  - ~~Coverage and service volume~~

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- Service level
- Available services

[New Zealand: Propose to include aircraft fleet capability]
[New Zealand: Propose to include aerodrome infrastructure capabilities and potential benefits to aerodrome approach operations over a non-SBAS environment]

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

## iv. Concept of Operations (CONOPS) Development and SBAS Implementation Team

A Concept of Operations (CONOPS) is a description of the characteristics of the service from the users' (such as airline staff and air traffic controllers) perspectives. The CONOPS should state the goals, strategies, policies and constraints affecting the service. It should include a clear statement of responsibilities of involved participants and stakeholders. Chapter 7.3 in ICAO Doc 9849 GNSS Manual provides reference about the elements, considerations and stakeholders involved for the development of CONOPS.

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 final outcome of ~~the first three phases~~ 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 proceduresdesign. 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.~~

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

A common goal of a regulator and service provider is to ensure that aircraft operators receive the benefits of SBAS based services in a timely and effective fashion while maintaining high standards

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of safety. The SBAS implementation team supports this goal by fostering a cooperative approach to the development of the standards, systems, procedures as well as the terms and conditions for regulatory approvals that respond to the needs of the aviation community.

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

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

## iii. 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.

[New Zealand: Propose to include the following-

1. Aerodrome Infrastructure (lighting, marking, signage, marking, aerodrome geometry, etc) in accordance with ICAO Annex 14, as items for consideration, especially in LPV-200/LPV-250 environment, NOTAM requirements, ongoing availability and continuity measurements;
2. Heliports in besides airports; and
3. En-route operations, namely RNP 0.3 En-route for helicopters, where SBAS can be used in lieu of RAIM coverage for the entirety of the route] in accordance with Doc 9613 PBN Manual, Chapter 7.

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**Commented [RG4]:** Added value of SBAS wrt GPS is the vertical and smaller horizontal guidance on the final approach

**Commented [RG5]:** To be discussed in the groups. This is not the main reason to implement SBAS.

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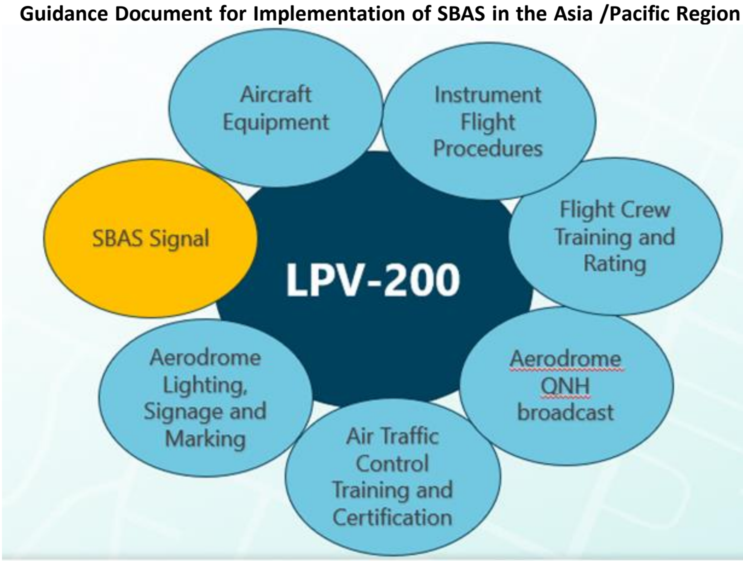


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## iv. System Deployment (For Implementation Type A and B)

- 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]**

## v.vi. 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:

[New Zealand: Propose to include ANSPs and Flight Procedure Office, as different States operate differently and ANSPs may be the one who review/design ATC procedures and Flight Procedure Designers may be a separate entity as well. We can consider defining it clear under Section 3]

- 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 information about predicted LPV unavailabilities to be provided to ATCOs
- 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

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~~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. 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 SLS procedure either on a simulator or actual flight.

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

Commented [VM6]: This is common to all procedures and hence not required.

- 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~~

## ~~vi.~~vii. Flight Check

A Flight Check can be considered to address the performance of the SBAS (Flight Inspection) and 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 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.

**Commented [RG7]:** To be discussed in the group as most of it could be deleted.

## vii. viii. Safety Assessment

The Safety Assessment and Certification process should show that the Service provided will be acceptably safe during and after the SBAS implementation. 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 should could comprise oftwo key components:

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[New Zealand:
Propose to amend the yellow sentence as safety assessment is part of the certification process with 'The safety assessment is part of the SBAS certification process and should fundamentally demonstrate that the Service Provided is acceptably safe once implemented'.
Propose to amend the green sentence as 'the level of regulatory involvement
Propose to amend the turquoise word as 'should']

- 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.
- Service Safety. This should demonstrate that the Certified System installed within the local ATM 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

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- ~~demonstration that local regulations and requirements have been met.~~

# ix. System Certification

There are three stages in System Certification

- System Approval
- Facility Approval
- Service Approval

- System Approval: System approval basic involves approving the design of the equipment. It spans activities ranging from Requirements Planning, System Acquisition, System Baseline, System Safety Assurance, etc. As far as possible the SBAS ground segment software should be developed as per civil aviation industry software standard like RTCA DO-178B or equivalent standards. Various documents/artifacts are generated as part of DO-178B severity level (i.e. Level B, D & E) process during entire life cycle of software development, e.g. PSAC, SRS, SDD, System Safety Hazard Analysis, Software Accomplishment Summary, Software Transfer Document, Master Integration and Test Plan, Change Impact Analysis (CHIA) Process, Safety Assessment Report, 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). OT&E is an essential step in the approval process of a system for operational use. OT&E performs an end-to-end, system-level testing. It is generally performed by the acquisition authority, or its designated representatives, as a last technical verification of the operational readiness of the system prior to declaring the system operational. OT&E provides a final verification performed in the operational environment that the performance of the SBAS signal-in-space (SIS) meets the requirements for accuracy, integrity, availability and continuity of service, including those requirements in Annex 10.

OT&E is also used to verify other important requirements ensuring the compatibility of the SIS with user equipment, as well as to verify that all elements needed for continuous operation of the system (such as trained personnel, operational and maintenance procedures, documentation, spare parts, etc.) are in place.

It is important to note that the safety case for an SBAS will not be based on the results of OT&E. Instead, it will be based on analyses performed prior to OT&E, in particular the fault tree analysis and the analysis of algorithm contribution to Hazardously Misleading Information (HMI), or "HMI analysis." The HMI Fault Tree Analysis is the key mechanism in demonstrating compliance with the quantitative SBAS integrity requirements. There are four types of analyses that support the completion of the fault tree quantitatively and they are the FMEA, algorithm PHMI Analysis, Safety Directed Analysis (SDA) and Qualitative Analysis (QA). The approved Fault Tree Analysis (FTA) is verified that the system satisfies the integrity requirements for RNP & APV phases of flight.

The OT&E will include the following tests: static testing, degraded

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Formatted: Heading 1, Tab stops: 1.18", Left operations testing, flight testing, and shakedown testing. During static testing, the system operates continuously with minimal intervention from the operators and maintainers for a specified period of time (e.g. 60 days), and data recorded by the system (as well as independent SIS receiving stations, if available) are collected, including Core constellation satellites (and possibly SBAS GEO) pseudorange and carrier phase measurements from all reference stations as well as SBAS broadcast messages and Core constellation satellites navigation data. This data recording phase is followed by an evaluation phase during which the data collected is analyzed, performance metrics are calculated, plots of various parameters are drawn, and system performance is evaluated and documented.

Degraded operations testing proceeds in a similar fashion as static testing, except that in this case, the testing is divided into a series of sub-tests during which various sub-systems (e.g., SBAS Reference Stations), are taken offline for a period of time as a means to verify the robustness of the total system as well as the performance of the SIS during degraded conditions. Here again, the data recording phase is followed by an evaluation phase during which plots and tables of results are generated and system performance is evaluated.

During flight testing, SBAS data is recorded during a set of flights using an appropriately equipped test aircraft. The data collected is processed after the completion of the flights, and navigation performance is evaluated.

Shakedown testing is concerned with the readiness of the system for continuous operational use. The objective of this testing is to verify that the installation of the equipment has been done according to the applicable rules and regulations, safety and security mechanisms are operational, personnel have been trained and can properly respond to potential malfunctions, system documentation and spare parts are available for operators and maintainers to fulfill their responsibilities, software can be loaded in the system, the system can be started up and shut down, system displays are providing the information that the operators need to assess the status of the different system components, etc.

• 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 could comprise of:

[New Zealand: Propose to amend to ‘should’]

- Concept Defined. Demonstration the concept of operations has been adequately

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- 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.

[New Zealand: Propose to include reference to the Safety Management System of the State/ANSP]

- 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 relevent ICAO SARPS.

[New Zealand: Propose to amend 'conforms with relevant ICAO SARPS' so as not to give impression it is all 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. ~~As Low as Reasonably Practicable.~~

[New Zealand: A comment for consideration whether the document should indicate 'As Low As Reasonably Practicable' as not sure all States have the same risk appetite / tolerance level in their State Safety Plan. Should we be generic and refer to States' risk appetite?]

- 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 a 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~~. 'A comprehensive Safety Case should be developed to address all the elements identified']

[New Zealand: Usually there would be a Safety Plan which lays out the safety process and the need for a Safety Case would already have been identified and commenced development at the early stage. Thus it is not only when all the elements have been addressed that the safety case can be developed. Propose that we indicate 'a comprehensive Safety Case should be developed to address all the elements identified']

## ~~viii.~~ x. Development of Regulations Related to SBAS for Aviation

Regulators, service providers and aircraft operators should all ascertain that a SBAS based operation

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Formatted: Justified, Indent: Left: 0", Hanging: 0", Space Before: 1.8 pt, Line spacing: Multiple 1.11 li 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. This is achieved by issuing a document approving the use of SBAS for various phases of flight operations with certified equipment and an approved flight manual. The approval should 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 sh~~all~~ould not be used for providing SBAS-based services unless certified by the State's regulatory authority where applicable.
- Any SBAS-based service/procedure should~~all~~ 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~~all~~ be approved by the State's regulatory authority, if applicable.

[New Zealand: Propose to amend 'unless approved by the appropriate authority as identified by the State' as not all States operate in the same manner and may not be approving the procedures but delegated to another entity to certify and carry the risk]

- ~~The details of SBAS installation including SBAS based service/procedure shall be published in AIP.~~
- Any aircraft should~~all~~ not utilize the SBAS based service/procedure unless theavionics requirement in terms of SBAS receiver equipage, pilot training

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- On-board SBAS receiver should~~all~~ be certified by the regulatory authority of the State.
- The SBAS service provider should~~all~~ carry out system checks and operational performance monitoring on a continuous basis. ~~in respect of accuracy, integrity, availability, and continuity should be prepared and shared with the regulator on a periodic 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 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.~~

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All the three approvals should follow six phase certification process:

- Phase One: Pre-Application. The ~~aerodrome operator and relevant stakeholders~~ANSP or SBAS operator should convene a meeting with the regulator (pre-application meeting) to ascertain all the requirements to be met, during the approval process.

[New Zealand: Propose to amend 'aerodrome operator' to 'SBAS operator or ANSP']

- 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 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. 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.

It is necessary to have a mutual understanding among all parties concerned by preparing various notices indicating the flow and necessary procedures to be followed to provide for the system's operation.

Regulation for SBAS Service Providers

- Any new SBAS wishing to broadcast SBAS must register and obtain approval from the ITU and coordinate frequencies with other countries.

[New Zealand: Propose to amend as 'Any new SBAS service provider']

- When a new SBAS service 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

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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.

[New Zealand: Propose to amend as 'obtain approval / agreement from the Regulator' as not all regulators 'approved' the plan and implementation methodology especially when we are do not define what 'approval' here comprises]

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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.

[New Zealand: A comment for consideration whether there is a need for a separate section for ANSP since it is SBAS service provider, regulator and airlines under this section xi, or SBAS service provider refers to ANSP as well?]

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## ix.xi. 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. TheTraining 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 involves training on the overview of GNSS and Augmentation systems, principles of operation of a SBAS, , differences between an ILS and SBAS based precision approach, differences to an ILS, the limitations, and advantages of aSBAS, 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.

- 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 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 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.~~xii. Operation Certification

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

[New Zealand: Seeking clarification the 'approvals for operation' refers only to the operational approval for airline only?]

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

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## ~~xi.~~xiii. Post-Implementation Review

Subsequent to the Commissioning of a 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 to As Low As Reasonably Practicable (ALARP).
- 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
- ~~Development of performance evaluation and verification tools~~
- ~~Regulatory clearance for signal up-link to SBAS GEO satellite~~

[New Zealand: should the last 2 points be captured in pre-implementation activities instead of post-implementation review?]

# 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

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Formatted: Justified, Space Before: 10.85 pt, Line spacing: 1.5 lines 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.

Typical O & M activities are listed below:

1. Monitor System Status
    a. Monitor Topology Display
    b. Monitor Significant Event Display
    c. Monitor Status Displays
    d. Archive Recorded Data
2. Control System Operation
    a. Change System/Subsystem modes
    b. Acknowledge Significant Events & Systems alarms and take appropriate actions
3. Update Operational Parameters
    a. GEO Satellite Maneuvers
    b. GEO Initial Position
    c. UTC/WNT Offset
    d. Earth Orientation Parameters
    e. PRN Mask
    f. IGP Mask
    g. System Account Information
4. Support System Maintenance Actions
    a. Isolate Fault
    b. Direct Maintenance Activities
    c. Verify Subsystem/System
    d. Upgrade/Download Software
    e. Modify System Configuration
5. Coordination with:
    a. Data Circuit Service providers on restoration of data communication circuits
    b. NOTAM Office to distribute SBAS Notifications in support of NOTAM generation.
    c. GEO Service provider for receipt of GEO initial Position and satellite maneuver data
    d. Various System Maintainers for the coordination of maintenance activities and for problem resolution.

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

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## a.b. Performance Indicators Assessment

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.

### a. 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).

### b. 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, State 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.

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**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 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 ~~receivers~~ signals to enhance the accuracy andreliability of position estimates.

The GAGAN system is a multi-stage project by the Indian Space Research Organization (ISRO), together with the Airports Authority of India (AAI) and the Director General of Civil Aviation (DGCA), to deploy and certify an operational Satellite Based Augmentation System (SBAS) for the Indian Flight Information Region (FIR), with expansion capability to neighboring FIRs. 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.

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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 DoD 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 WAAS avionics using the GAGAN SIS for any approved phase of flight. The broadcast SIS provides messaging (data on GPS and Geostationary Earth Orbit (GEO) satellites).

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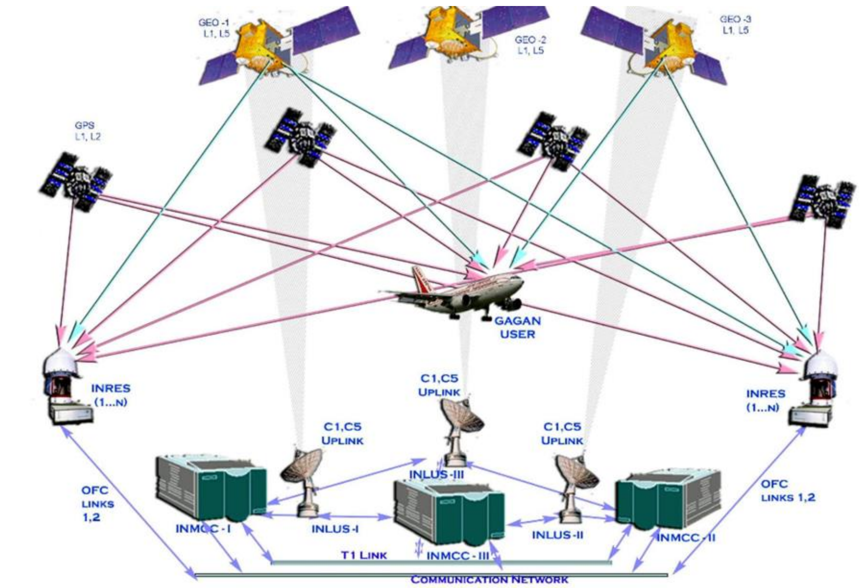
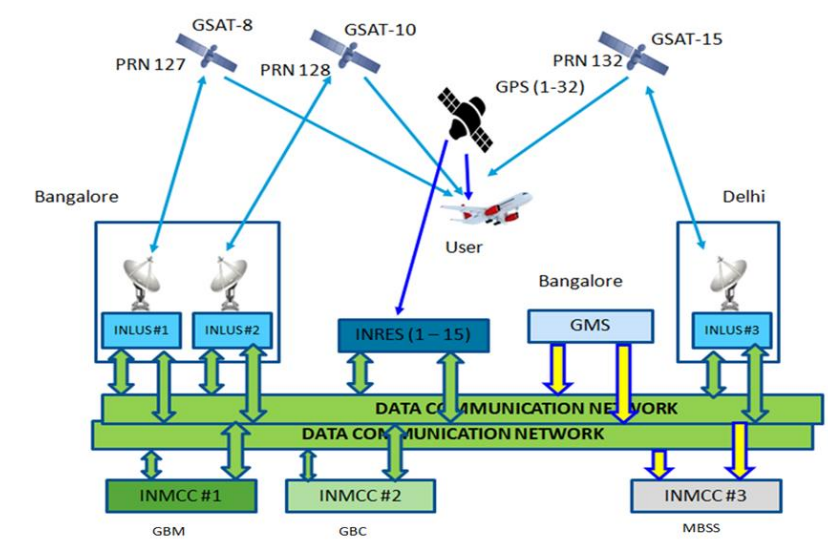
GAGAN system's architecture has two segments, one is ground segment and the other is space segment. At present the ground segment consists of 15 reference stations spread all over India and three master control centres (two are in operation and one in shadow mode). These 15 reference stations are stationed 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.



**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:

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

GAGAN's APV-I/1.5 service has the following characteristics:

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

On stormy days, APV-I/1.5 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.

**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.

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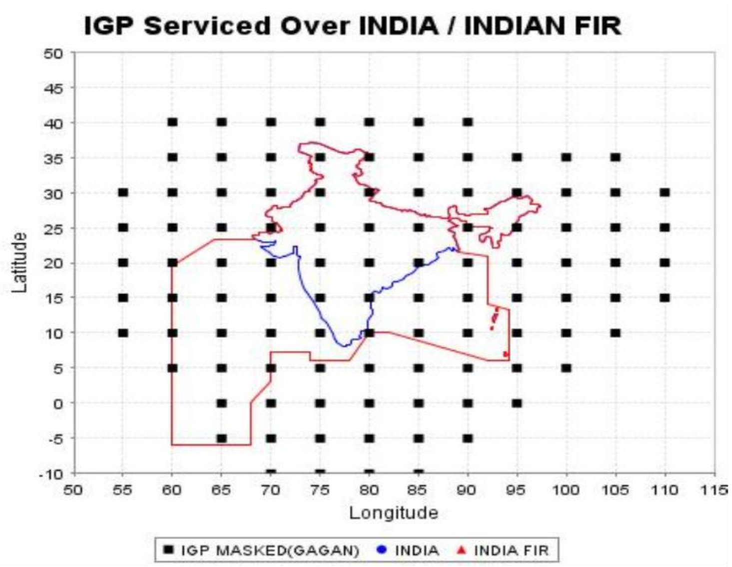

IGP Serviced Over INDIA / INDIAN FIR
Latitude
Longitude
IGP MASKED(GAGAN)
INDIA
INDIA FIR

### 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~~.


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***

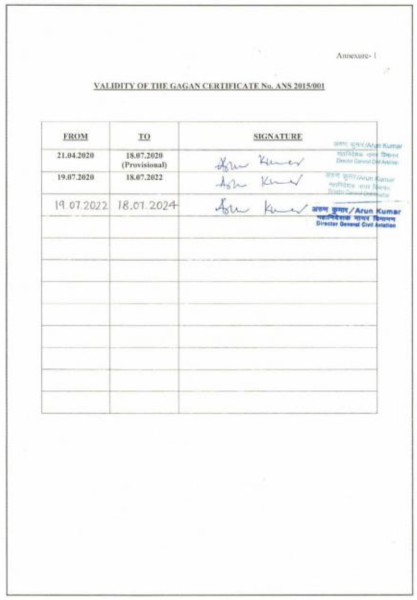
***GPS Aided GEO Augmented Navigation (GAGAN) System***

***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) | |
| 19.07.2020 | 18.07.2022 | |
| 19.07.2022 | 18.01.2024 | अरुण कुमार/Arun Kumar Director General Civil Aviation |
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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/

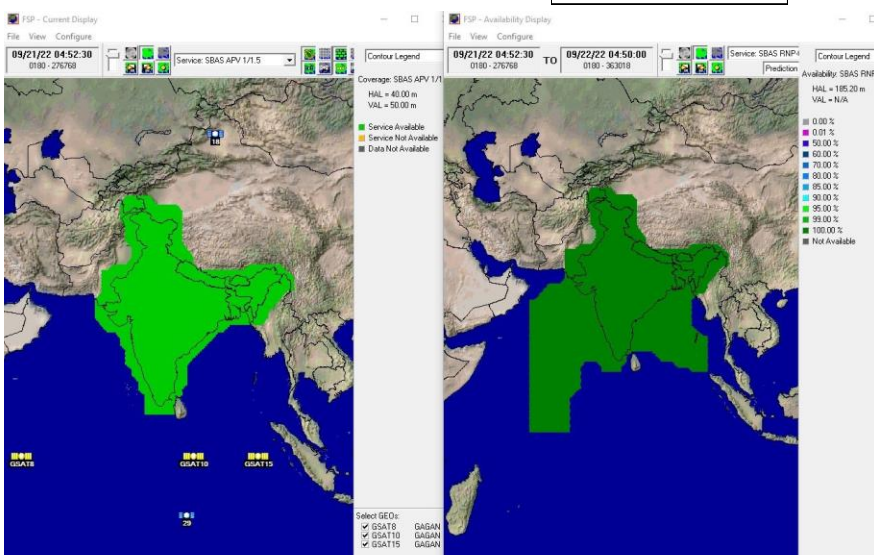
**A)** VIDF/VABF/VECF/VOMF **B)** 1505190530 **C)** PERM

**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