CONTINENTAL COST-BENEFITS ANALYSIS (CBA) OF THE SBAS IMPLEMENTATION IN AFRICA.

Phase II: Final Report
7th January 2025

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List of acronyms

ACI	Airport Council International
ADS-B	Automatic Dependent Surveillance-Broadcast
AEC	African Economic Community
AFCAC	African Civil Aviation Commission
AFRAA	African Airlines Association
AfSA	African Space Agency
AIS	Automatic Identification System
ANSP	Air Navigation Service Provider
ANSPs	Air Navigation Service Providers
AOC	Air Operator Certificate
APIRG	AFI Planning and Implementation Regional Group
ASECNA	Agency for Aerial Navigation Safety in Africa and Madagascar
ATCO	Air Traffic Controller
ATM	Air Traffic Management
AU	African Union
AUC	African Union Commission
CAA	Regional Civil Aviation Authority
CBA	Cost Benefit Analysis
CCF	Central Control Facility
CPF	Central Processing Facility
DGAC	Direction Générale de l'Aviation Civile
EGNOS	European Geostationary Navigation Overlay Service
EGNOS	European Geostationary Navigation Overlay Systems
ESSP	European Satellite Services Provider
EU	European Union
EUSPA	European Union Agency for the Space Program
GAGAN	GPS Aided GEO Augmented Navigation
GBAS	Ground-Based Augmentation System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
ICAO	International Civil Aviation Organization
JPO	Joint Programme Office
KASS	Korea Augmentation Satellite System
KPI	Key Performance Indicators
MCC	Mission Control Centre
MOPS	Minimum Operational Performance Standard
MSAS	MTSAT Satellite Augmentation System
NLES	Navigation Land Earth Stations
OS	Open Service
PBN	Performance Based Navigation

PPP	Public-Private Partnership
REC	Regional Economic Community
RIMS	Ranging and Integrity Monitoring Stations
RNP	Required Navigation Performance
RRC	Regional Regulatory Committees
SAATM	Single African Air Transport Market
SARP	Standards and Recommended Practices
SB	Service Bulletin
SBAS	Satellite Based Augmentation System
SDD	Service Definition Document
SES	Single European Sky
SIL	Surveillance Integrity Level
SIS	Signal-In-Space
SoL	Safety of Life
SouthPAN	Southern Positioning Augmentation Network
UAV	Unmanned Aerial Vehicle
WA	Working Agreements
WAAS	Wide Area Augmentation System
WACAF	Western and Central African Office
WP	Working Package

EXECUTIVE SUMMARY

The second phase of the Cost Benefit Analysis aims to define the **governance and institutional framework** of African SBAS, as well as to recommend the most optimal **technological development** model, including the concepts of technology transfer and risk Assessment.

Regarding **Institutionalization**, the objective of the task is to define the African SBAS Institutional model, encompassing programme governance, organisation, funding, and service provision to identify the critical aspects towards the complete operationalisation of the SBAS Programme and services on the continent.

Various tasks must be performed for the full operationalization of SBAS in Africa. These can be divided into four layers: Programme Governance and Oversight, Programme Management, Service Provision, and Certification. Each layer includes several roles that should be filled when implementing the SBAS programme, which are briefly detailed below:

Responsibilities	Roles	
Political oversight	**Oversighting Organization** Organization in charge of supervising the programme and policy implementation at a continental level	**Safety and Regulation Oversighting Organizations** Organization in charge of promoting the highest common standards of safety and ensuring regulatory harmonisation
Programme management	**SBAS Owner** Organization in charge of providing strategic direction and ensure the sustainability of the service	**SBAS Programme Manager** • Upstream: Service exploitation and programme management activities • Downstream: Market development and user uptake activities
Service provision	**SBAS Service Provider** Organization responsible for delivering SBAS services, specifically the Safety of Life Service (SoL), in accordance with ICAO SARPs	**ANSPs and Other Users** The final users of SBAS, using the system data and services for different applications
Certification	**National CAAs** Organization responsible for providing regulation for the use of SBAS, ensuring its supervision and potential certification	**Safety and Regulation Oversighting Organizations** Organization in charge of certification and regulatory oversight activities under delegation of the CAA's

Figure 1: SBAS roles and responsibilities

To build the SBAS institutional model in a comprehensive manner, decisions must be made on three levels: number of entities involved, ownership model, and centralization model. The different possibilities existing are illustrated in the following figure:

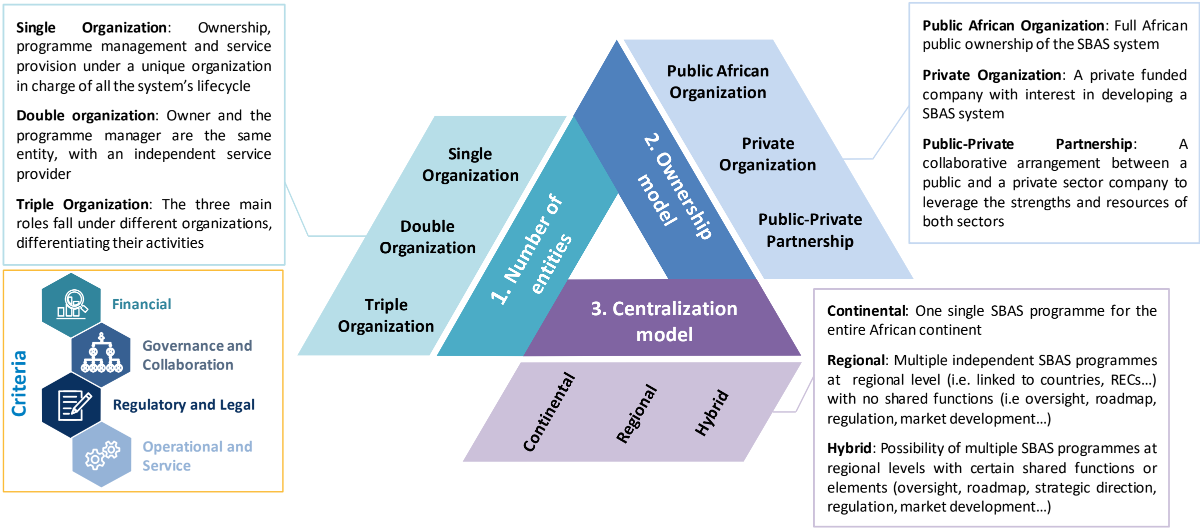
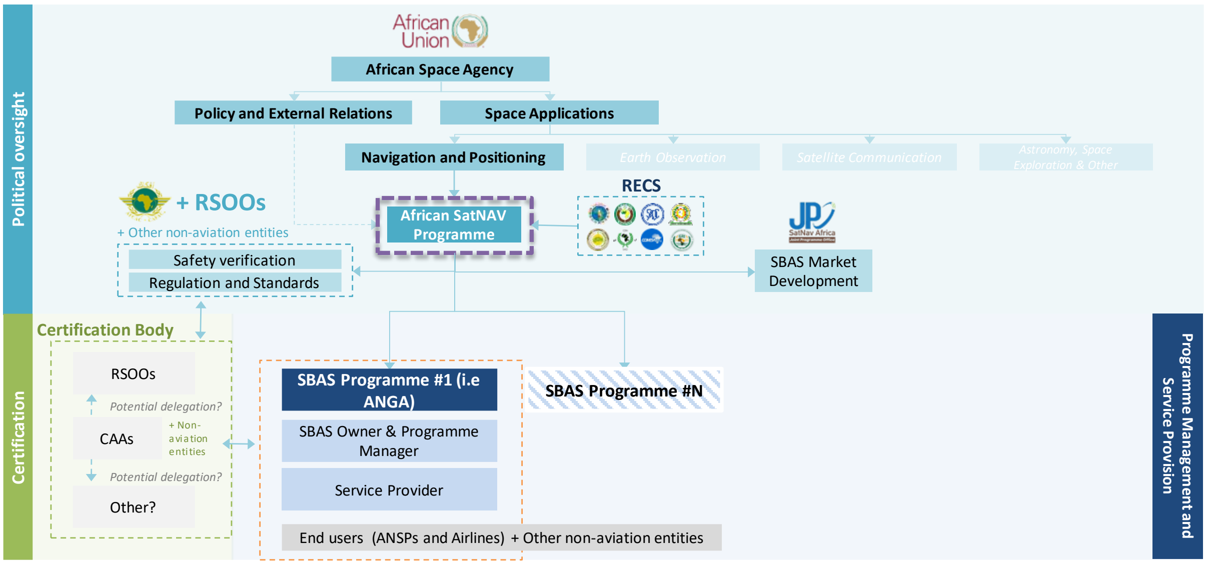


Figure 2: SBAS model alternatives and selection criteria

To derive the recommendation for Africa, these options were compared via a multi-criteria analysis combining financial, governance, regulatory, and operational aspects. The chosen option for Africa is a **hybrid centralization model, with full public ownership** and composed of either **one or two organizations** in the programme management and service provision layers. The summarized reasoning for this selection is presented:

- **Hybrid centralization model**: The existence of a central entity providing a common policy will ensure coordination over the different initiatives, unified regulatory framework and service levels, and help the programme achieve public African interests. Leverages on the benefits of decentralization as a continental model may bring about resistance from countries, and exploit the legislative powers of the RECs, who can help enforce the regulation. Finally, this model builds on ongoing initiatives (EGNOS V3, ANGA).
- **Public ownership model:** African countries have full control over the system and its roadmap, and private capital entails a search for profitability in an SBAS service with limited commercial potential initially.
- **Single or dual organization:** Leaving the door open to multiple SBAS programmes means that each could freely choose their internal organisation. However, it is recommended to opt for single or dual organisations.
    - Single: Concentrating all functions avoids resource duplicities and streamlines governance. However, this relies on finding an organization that can take on such a complex role.
    - Double: Opting for a separate service provider introduces a level of separation and specialization in the management and operation.

A single policy-making body within the AU would set general policies and an overall African SBAS Program roadmap, providing oversight over individual SBAS programmes. It would also push for continent-wide standards for SBAS performance, ensuring consistency in service, quality and reliability, and seamless operation of SBAS users between different SBAS regions. However, this hybrid approach would provide the opportunity to build SBAS capabilities in stages starting with regional systems to allow groups of countries to implement SBAS with certain independence. Unified under a single oversighting body, these regional systems would evolve over time to form a comprehensive, continent-wide SBAS, ensuring that aircraft can seamlessly transition between different airspaces without losing SBAS service.



Organisation and service provision of an individual SBAS programme to be detailed in the next sections

Figure 3: African SBAS Organisational Structure

The proposed solution involves an "African SatNAV Programme", at a continental level, leveraging the approved structure of the African Space Agency and the Outer Space Strategy. **The African SatNAV Programme would therefore be embedded into the Navigation and Positioning pillar and would contain all activities regarding SBAS in Africa.** This African SatNAV Programme would be led and coordinated by the African Space Agency and receive contributions from the RECs, AFCAC, the RSOOs, as well as the SatNAV Africa JPO, as illustrated above. The main responsibilities of each of the actors are included below:

African Space Agency: Within the scope of the African SatNAV Programme, its responsibilities would include overall programme supervision and oversight, policy and strategic guideline definition at the continental level (types of services, targeted users, overall roadmap…), and ensuring SBAS development is aligned with African priorities (Agenda 2063, SAATM…).

AFCAC: Its role within the African SatNAV Programme would revolve around the unification of SBAS standards and regulations across the continent to maintain compliance with international standards set by entities such as ICAO.

Regional Safety Oversight Offices (RSOOs) These RSOOs, together with AFCAC, would be responsible for regulatory harmonisation through the development of the model legislation pursuant to the relevant ICAO Annexes. These would liaise between AFCAC and local civil aviation authorities (CAAs), ensuring that the model laws are transposed into the respective member States' legislation and that SBAS services are effectively implemented at a regional level while adhering to the continental framework.

Regional Economic Communities (RECs) The proposed roles of the RECs could be to act as a liaison between the African SBAS Programme and the individual initiatives, contributing to the African SBAS Programme's policies and helping impose binding policies and laws in their areas of influence.

ICAO PIRGs: Advisory and engagement in the institutionalisation, planning and implementation of SBAS technology in Africa.

SatNAV for Africa JPO: SBAS market development at a continental level. This would entail promotion campaigns, industry forums, collaborative demonstrations, market monitoring and analysis, capacity building and user adoption support.

Below this first political layer, there would be a number of individual SBAS programmes, with great levels of independence albeit subject to the general policies set out by the African SBAS Programme.

These individual SBAS programmes would be free to implement their desired internal organisational, although single or dual-entity approaches are recommended. In the case of a **dual organisation,** the responsibilities would be as follows:

- **SBAS Owner + Programme Manager:** In charge of ensuring the financial and technical sustainability of the service. Ultimate responsibility for the individual SBAS programme and therefore in charge of approving both the evolution of the SBAS mission and the related roadmap. Publish the SBAS SDD as proposed by the SBAS Service Provider and authorize the declaration of the SoL (Safety of Life) service once the Readiness Review process is successfully passed.
- **SBAS Service Provider:** In charge of operating and maintaining the system and delivering and monitoring the service according to the standards defined in the SDD. Establish Working Arrangements and Agreements with the ANSPs, Aerodrome Operators, or any other organizations which are operationally responsible for SBAS-based procedures.

  *In the case of a **single organisation**, this entity would combine all responsibilities of the Programme Manager and Service Provider detailed above.*

Certification body:

Entity responsible for certifying the SBAS service Provider and system. Typically, the national Civil Aviation Authority would oversee this certification process. However, to streamline the certification process, the CAAs could delegate this function to another entity (either existing or a body of new creation), which could certify services in several states. For example, a Level 3 RSOO would be responsible for granting such certification, always under the oversight of the national CAA.

Regarding Service Provision itself, there are two key documents that form the basis of the SBAS Service Provision Scheme, governing the SBAS Service and the relationships between the key actors. The **Service Definition Document (SDD)** describes the Service itself as well as the terms and conditions for accessing the service. While the **Working Agreement** lays out the terms and conditions under which the SBAS service is provided, and the working procedures and interfaces between the organisations. These documents must be drafted for any service provided by the SBAS Service Provider. Typically, these include the Safety of Life (SoL) Service, Open Service and Data Access Service, but could include additional services such as PPP, RTK, or SoL for Maritime Users. A representative service provision scheme for SoL service for aviation is included below:

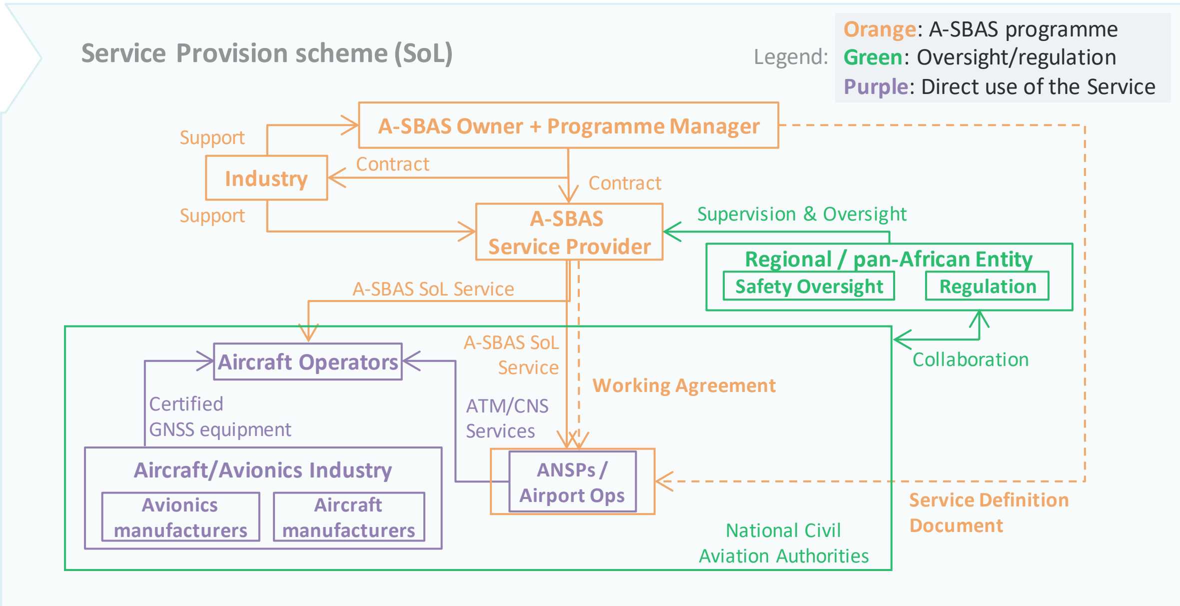


Figure 4: Illustrative Service Provision Scheme

Regarding economic viability, Phase I demonstrated the positive overall business case of SBAS implementation for African society, mainly due to the benefits to airspace users and ANSPs. However, deployment of SBAS requires significant capital (**200 M$** per system) and operational (**20 M$/year** and system) investment. Additionally, there is limited direct revenue generation, as no revenue generation is expected through the Safety of Life, as no costs or charges related to SBAS will be imposed to airspace users who do not use such technology. This situation drives the need to identify funding mechanisms to ensure the viability of the programmes. Funding would be received on two levels: The political layer of the African SatNav Programme should be funded through mechanisms typically used by AfSA, while individual SBAS Programme leaders would cover their initiatives independently using public funds, multilaterals, and grants.

A high-level roadmap towards SBAS institutionalisation is presented below:

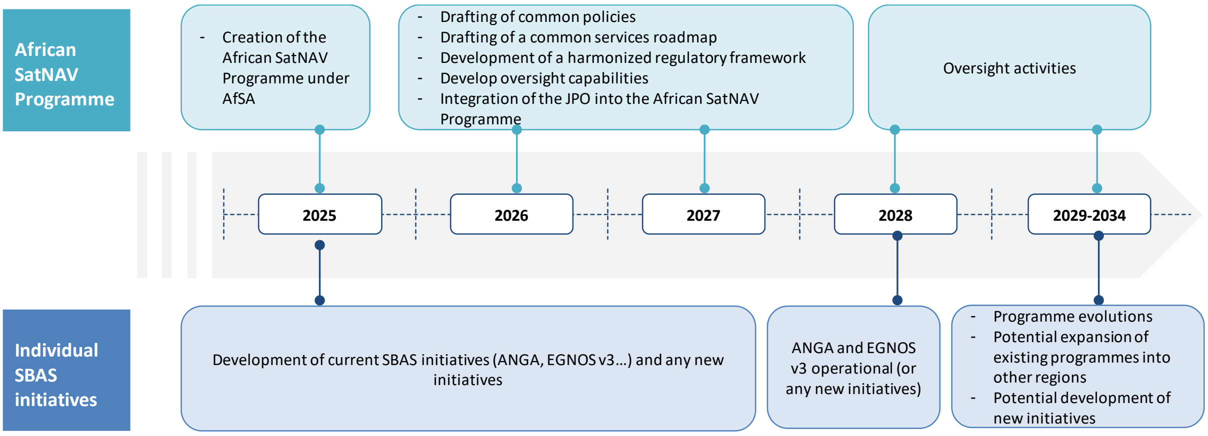


Figure 5: SBAS programme roadmap

Regarding **Technology**, the objective of the task is to define the most appropriate SBAS system development approach while conducting risk analysis and providing recommendations for seamless implementation.

An SBAS system comprises various subsystems, which need to operate cohesively to enhance the GNSS signal and provide services to users.

- Space Infrastructure: Corresponds to two geostationary satellites (GEO) equipped with navigation payloads that transmit GNSS-like signals carrying SBAS information.
- Ground Infrastructure: Includes a Reference Integrity Monitoring Stations (RIMS), Mission Control Centres (MCC), Navigation Land Earth Stations (NLES), and a communication system for data collection, processing, and transmission.
- Airborne Infrastructure: Is composed by a compatible antenna, receiver, and Flight Management System (FMS) to process SBAS signals.

Additionally, a service provision layer includes all aspects related to delivering the service to SBAS users and the operation and maintenance of the ground-based infrastructure.

There are three main types of system development options for an SBAS system, with increasing degrees of involvement from local entities: (i) Full technology import, (ii) Technology Transfer, (iii) Full independent system development. The key advantages and drawbacks are illustrated below:

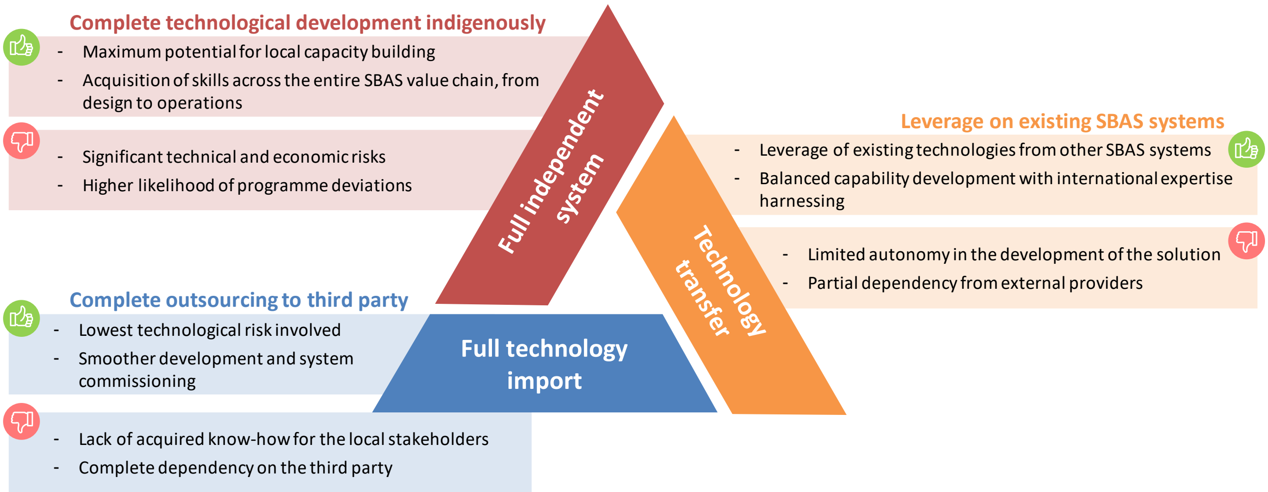


Figure 6: SBAS system development options

The three development options are observed worldwide with Korea being a clear example of technological transfer agreement with the participation of domestic entities and international contractors.

Programme	Development type		Owner	Key Contractor (s)
WAAS	1	Independent system development	Federal Aviation Administration	Raytheon Technologies
EGNOS	1	Independent system development	esa European Space Agency	ThalesAlenia Space; AIRBUS DEFENCE & SPACE
	1	Independent system development	JCAB	NEC
KASS	2	Development through technology transfer	KAIA	ThalesAlenia Space; ETRI; KARI
SouthPAN	3	Full technology import from third party	Full development responsibility delegated to contractors	LOCKHEED MARTIN; gmv

Figure 7: SBAS development options - international benchmark

The recommendation for African SBAS is dependent on the SBAS subsystem:

- **Space Infrastructure:** Development through technology transfer: Typically, SBAS satellites are multi-purpose, commercial communication satellites that carry out an additional SBAS navigation payload. This trend is seen in all SBAS programmes around the world (EGNOS, GAGAN, KASS, WAAS, MSAS…).

  Considering the international references, the widespread model for the SBAS space segment is to host an SBAS payload in telecommunications GEO satellite, offering a cost-effective means to access satellite resources without the need to construct and launch dedicated satellites, an option that would significantly increase the costs of the

SBAS programme. It would be recommended to host the SBAS payloads in a mission owned and operated by an African entity, either private or public such as Nigcomsat or Nilesat.

Alternatively, due to the orbits and geostationary satellites, and the similar geographical longitude of the European and African continents, the African SBAS payload could also be hosted in a European telecommunications satellite (Eutelsat, Intelsat, Amos, SES…).

- **Ground infrastructure:** **Development through technology transfer**: There are several industry players with proven capabilities of developing and implementing complete SBAS systems. These include Thales Alenia Space, Airbus, Lockheed Martin, GMV, Raytheon, and NEC Corporation. ANGA, in collaboration with its international partners, has developed an operational testbed to showcase its advancements in its SBAS. This has paved the way towards ANGA's SBAS initial non-operational services, which have been broadcasted effectively on L1 band since 2020. This has been followed up by a successful DFMC demonstration in 2023, the first of its kind in any SBAS programme in the world. Additionally, flight demonstration in Togo and Cameroon, have been performed.

  The SBAS ground infrastructure and system is the most complex subsystem of the SBAS Programme. Therefore, the recommendation is to opt for a Technology Transfer in terms of the overall system design, leveraging existing technology in order to greatly reduce the development costs of the programme (factors of 300% to 400% due to transition from low to high TRLs). The system design would be developed by a Joint Task Force composed by an African entity with collaboration from international partners, following the example of KASS.

  The most critical parts of the system itself should be contracted to an experienced international contractor with proven capabilities, who will develop a system according to the specifications and requirements developed by the Joint Task Force

  The operation and maintenance should be performed independently by the SBAS Service Provider, leveraging the use of local personnel. Prior to this, a training stage should be performed in which the international partner.

- **Airborne infrastructure:** **Full technology import from third party.** There are several established players, namely Rockwell Collins, Honeywell, CMC, and Thales with multimode receivers and Flight Management Systems with SBAS NAV and SBAS LPV capabilities tailored to the main aircraft manufacturers (Airbus, Boeing, Embraer…). Airborne equipment falls outside the scope of all operational SBAS Programmes in the world.

  The SBAS airborne equipment market is largely dominated by private parties, which have solutions integrated in all the main aircraft models, which operate in a highly competitive market. As the selection of the SBAS airborne equipment is driven by the users, they will have the ultimate choice of selecting the solution which best fits their needs.

It is therefore recommended not to explore acquiring indigenous capabilities in this market, as it will be difficult to compete with the private players in the market, and it is not considered to be of significant added value in comparison with the ground segment.

The key **project risks** arising from the development option selected for each subsystem have been identified and classified according to their severity and likelihood. A selection of the most relevant is now presented, along with the main mitigation actions.

Table 1: Summary of project risks

Segment	Risk	Mitigation
Space	**Third-party dependence**: SBAS space segment hosted on a independent satellite mission	Establish a partnership with the satellite operator, increasing the level of commitment
User	**Limited user acceptance and fleet readiness**: Users are not knowledgeable about SBAS technology and are unwilling to equip their aircraft	Market development agent of the African SBAS Programme (SatNAV JPO) to lead user uptake activities (business cases, demonstrations.)
	Limited financial capabilities to invest in SBAS equipment	Establish financing programmes under multilaterals (AFDB.) to help airlines finance their investments
Ground	**Delays and cost overruns** in development phase	Realistic schedule and cost estimations during tender preparation phase, with the aid of international partners
	Inadequate performance or service area	Selecting a prime contractor with demonstrated capabilities in SBAS system development, to develop a system appropriate to the ionospheric conditions of equatorial Africa
	Limited capabilities of personnel in SBAS operation and maintenance	Perform capacity-building exercises prior to entry into operations by the international partners and/or prime contractor

To mitigate this risk, it is proposed to follow the risk management process derived from NASA's Risk Management Handbook and is based on the Continuous Risk Management (CRM) principle. The CRM process encompasses five recurring stages: Identify, Analyse, Plan, Track, and Control. These stages function concurrently, allowing for the simultaneous reporting of individual risks into the risk database.

To manage this complex process in the SBAS programme, a series of risk-management committees are proposed, illustrated in Figure 44.

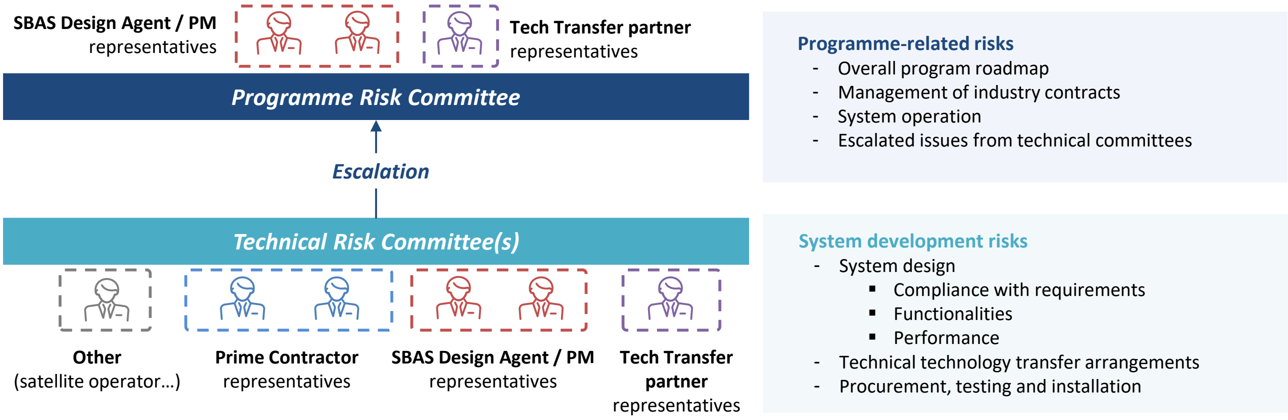


Figure 8: Risk management committees

First, a technical risk committee, formed by representatives of the prime contractor, the SBAS Design Agent / Programme Manager and Technological Transfer Partner, as well as other representatives upon need (i.e. satellite operator) would deal with the identification, assessment, tracking, and monitoring of all risks related to system development, focused on technical aspects (compliance with requirements, system performance, procurement…). Any issue that cannot be responded to will be escalated to an upper echelon, the Programme Risk Committee, as indicated in the CRM process.

This Programme Risk Committee would be formed by members of the SBAS Design Agent / PM and the Technological Transfer partner (although representatives from other entities could be invited upon need). They will be tasked to resolve the escalated issues from the technical committees, as well as perform the complete CRM process for other strategic topics key to the programmes' development, such as deviations to the roadmap, management of industry contracts... Finally, they will also be tasked to deal with the risks related to the operation of the system after entry into operations.

This risk management process and governance framework aims to provide a sound methodology to identify, assess and respond to all the risks that may come up in the development of SBAS capabilities in Africa.

0. Introduction

The objective of the EU-funded project "Operationalization of the Single African Air Transport Market (SAATM) – support to the African Civil Aviation Commission (AFCAC)" is to ensure technical and financial support to the AFCAC as the designated Execution Agency for the implementation of the SAATM, in order to strengthen the aviation sector in Africa and lifting the main obstacles to its development at a continental level, contributing the growth and regional integration.

As part of the wider Operationalization of the SAATM project, EASA wishes to support the AFCAC in the development and implementation of a Satellite-Based Augmentation System (SBAS in Africa).

0.1 Context

The strategy for the implementation of core GNSS and its augmentations has been developed and updated along the AFI Planning and Implementation Regional Group (APIRG) meetings since early 2001, including the implementation of SBAS in the continent.

APIRG/17 meeting concluded on the need for an independent Cost-Benefit Analysis (CBA) to understand the impact of SBAS implementation in the Region, with the goal of supporting the decision-making process. During the Declaration of Lomé, in March 2018, the AU Member States requested the African Union Commission (AUC) to coordinate this CBA study.

Phase I of this CBA, centred on the economic attractiveness of SBAS at a continental level for aviation stakeholders, was conducted throughout 2021-2022, in the scope of the EU-funded Technical Assistance to the AU – Infrastructure Support Mechanism. The results of this workshop were presented at the SBAS Continental Workshop, held from 30 to 31 May 2022 in Kigali, Rwanda, to air, maritime, and agriculture experts from the 55 AU Member States, delegates from the aviation industry associations and sector experts from the Regional Economic Communities (RECs).

As part of the next steps of the Continental Workshop, it was concluded that the AUC and AFCAC, in collaboration with their partners, should complete the CBA study by developing two additional areas:

- Governance and institutional framework.
- Feasibility study of African GNSS/SBAS technology transfer and Risk Assessment.

In this context, the objective of this mission is to procure expertise support in the areas of air transport economics and air transport law to support the AFCAC in the completion of the CBA on SBAS implementation for Africa.

As a result of Phase I, some recommendations emerged:

- Phase I demonstrated the appeal of implementing SBAS in the African continent due to the relevance of this technology in key African industrial sectors. It is highly attractive for the economic development of the industry on the continent, with extremely positive results from the conducted CBA, demonstrating the high economic attractiveness of SBAS supported by the positive values in all the evaluated financial indicators.

- There was a call to prepare a study on institutionalization and technology. This study would aim to structure the organizational framework for service provision and identify infrastructure needs for Af-SBAS: financing, development, execution, etc.

0.2 Objectives

The objective of the continuing project is to support the AFCAC in the completion of the CBA on SBAS implementation for Africa. To achieve this goal, the following information must be identified:

- **Governance and organization:** Definition of main functions within the programme and identification of roles and interactions between programme stakeholders, with the aim of defining the overall governance structure.
- **Regulation and oversight:** Definition of overall regulatory and standarisations framework, including the certification layer and programme oversight activities
- **Funding:** Definition of the funding needs and the potential funding mechanisms.
- **Service provision:** Definition of the service provision and liability schemes that define the interactions between the stakeholders in the service provision layer.
- **Technology:** Definition of the development model for African SBAS, ranging from full independent system development to direct import from a third country, as well as the possible transfer of technology arrangements.

0.3 Methodology

The support to AFCAC is structured according to the steps defined in Figure 9.

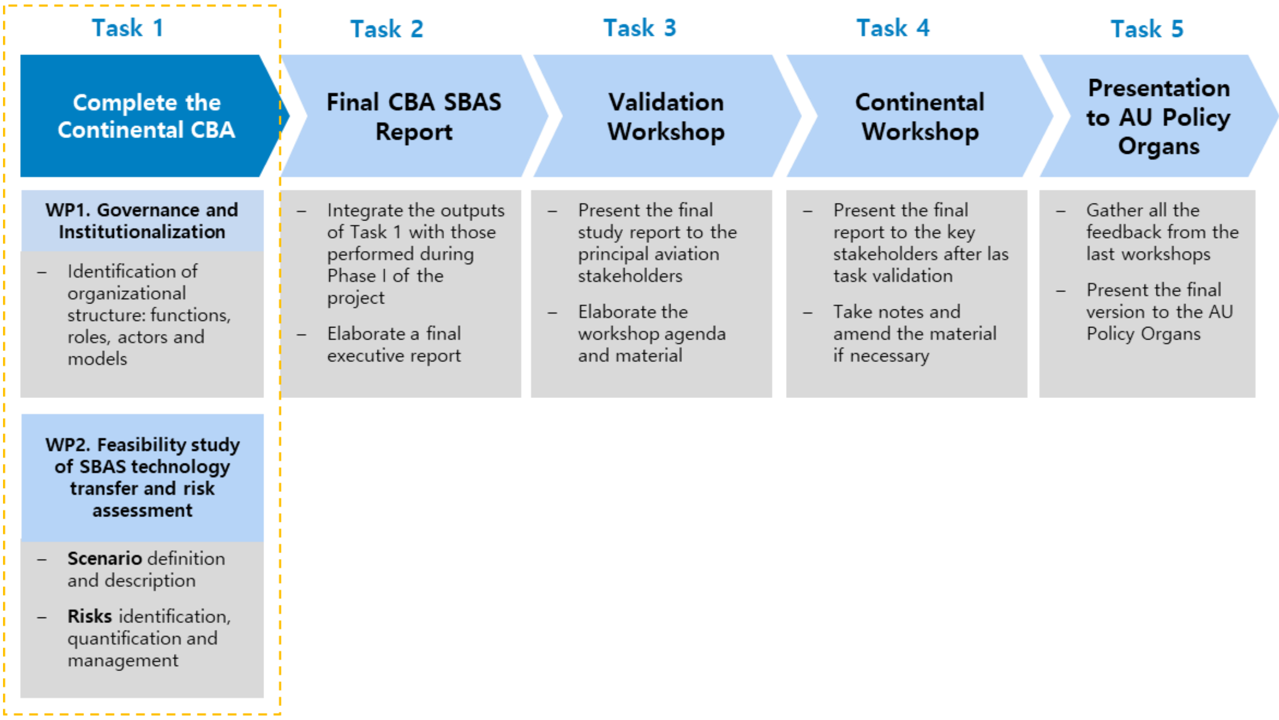


Figure 9: Overall methodology

Task 1 has been divided into two distinct working packages (WP)

WP1. Organisation and Institutionalisation:

The implementation of African SBAS needs an adequate institutionalisation, defining roles and allocating functions and responsibilities. The main objective of this work package is to understand which the optimal organizational model is to provide SBAS services to the users in Africa. This will be performed following a seven-step approach, illustrated in Figure 10.

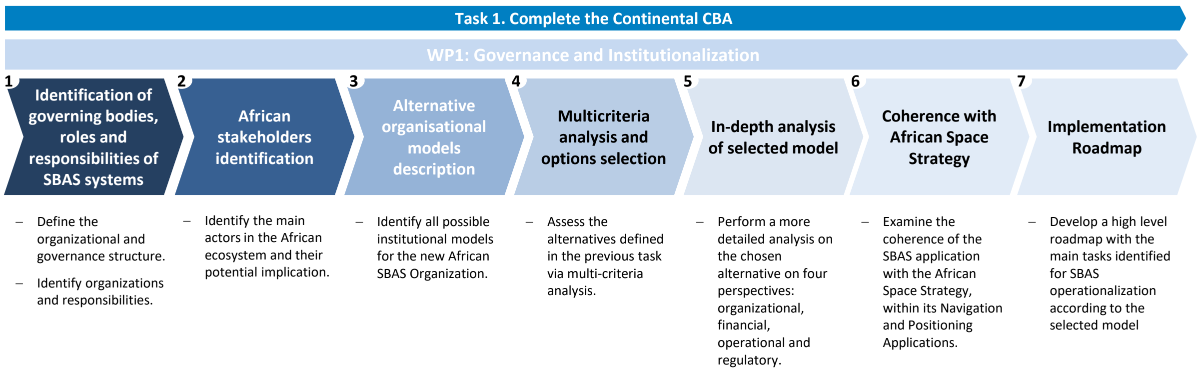


Figure 10: Governance and Institutionalisation methodology

WP2. Feasibility study of GNSS/SBAS technology transfer and risk assessment:

This second work package involves the definition and description of how the SBAS system will need to be developed, identifying whether it will be a full independent development by African entities, a technology transfer from an existing system or a complete technology import. The SBAS system will be broken down into its different subsystems to identify the best solution for each.

After defining and selecting the recommended scenario, a risk analysis will be conducted to assess threats and establish recommendations and actions to achieve a seamless and problem-free implementation of the system.

This two-step approach is illustrated in Figure 11.

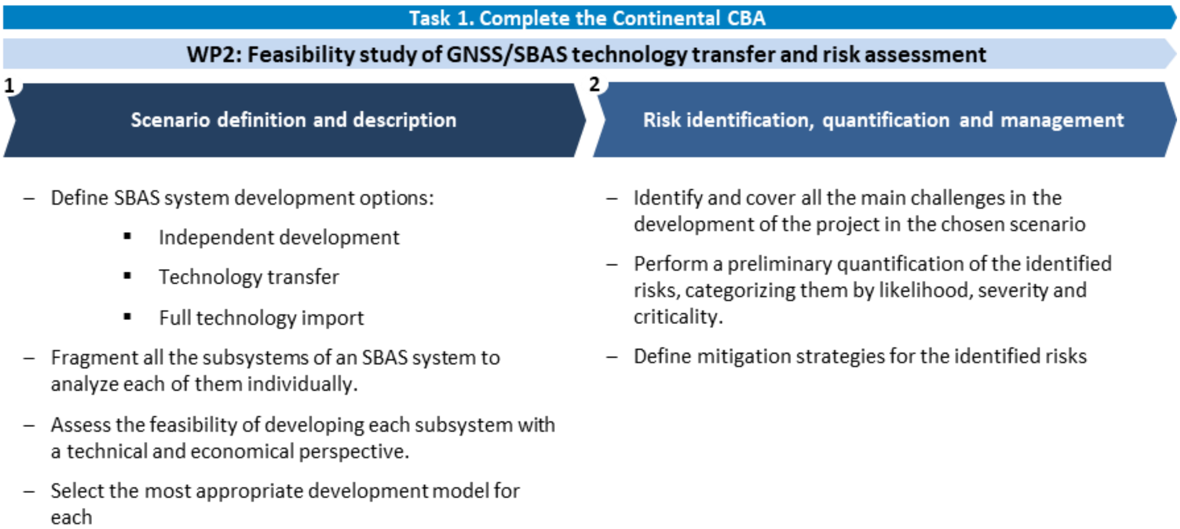


Figure 11: Feasibility study of GNSS/SBAS technology transfer and risk assessment methodology

Work Package 1: Governance and institutionalisation

1. Identification of Governing Bodies, Roles and Responsibilities of SBAS Systems

1.1 Basic Components of an SBAS Implementation

When designing an SBAS programme from its inception, several tasks must be performed on the following layers:

Organisation, governance and oversight:

- Identification or set up of organisations that will be involved in the programme
- Development of SBAS policies and roadmap, using lessons learned on the implementation of SBAS in other regions (namely in the EU)
- Set up the oversight functions

Infrastructure:

- Designing, developing, and qualifying the SBAS system and infrastructure, as well as elaborating product evolution agreements with third parties for the procurement of the solution.
- Estimating the project costs and identifying appropriate sources of funding to carry out the project, enabling the system's smooth development.
- Deploy the SBAS system and infrastructure

Service Provision:

- A service definition document must be published, clearly defining the SBAS services to be implemented
- Service provider selection or set up. An entity specialised in the operations and provision of satellite-based services for critical missions must be identified or set up, making clear its responsibilities and limitations.
- Working agreements must be set up between the SBAS end users and the service provider, as well as contracting arrangements for system maintenance and with telecom providers for the SBAS ground infrastructure

Regulation

- Development of a regulatory framework applicable to all aspects of the SBAS programme.
- The certification of the SBAS system and SBAS Service Providers by appropriate bodies to provide navigation services that comply with ICAO SARPs (Standards and Recommended Practices) and RTCA MOPS (Minimum Operational Performance Standard).

1.2 SBAS Responsibility Layers Definition

Having understood the necessary steps that must be taken towards SBAS implementation in Africa, several layers of responsibility and roles must be defined, to later allocate specific entities into these roles. Based on these tasks as well as the study of the two fully operationalized SBAS systems (WAAS and EGNOS), several layers of responsibility can be identified, with their corresponding activities (high level, more information to be found in section 3.3):

Table 2: SBAS programme layers of responsibility

Layers of responsibility	Activities
Political Oversight	In charge of the review, monitoring and supervision of the programme and policy implementation at a continental level, the definition of the overall programme roadmap and the setup of a general regulatory framework guiding the programme, as well as a common certification process for system and provider.
Programme Management	Management of the SBAS programme on two layers • Upstream: Programme exploitation, system development and deployment • Downstream: Market development, user engagement and service uptake activities
Execution	*If delegated by the Programme management layer.* In charge of the development and deployment of the SBAS system and infrastructure and in charge of establishing contracts with the industry.
Service Provision	Establishment of arrangements with end users and service provision, as well as operation and maintenance of the systems.
Certification	In charge of regulation and certification of SBAS services

As an example, the high-level WAAS and EGNOS governance structure is presented in Figure 12:

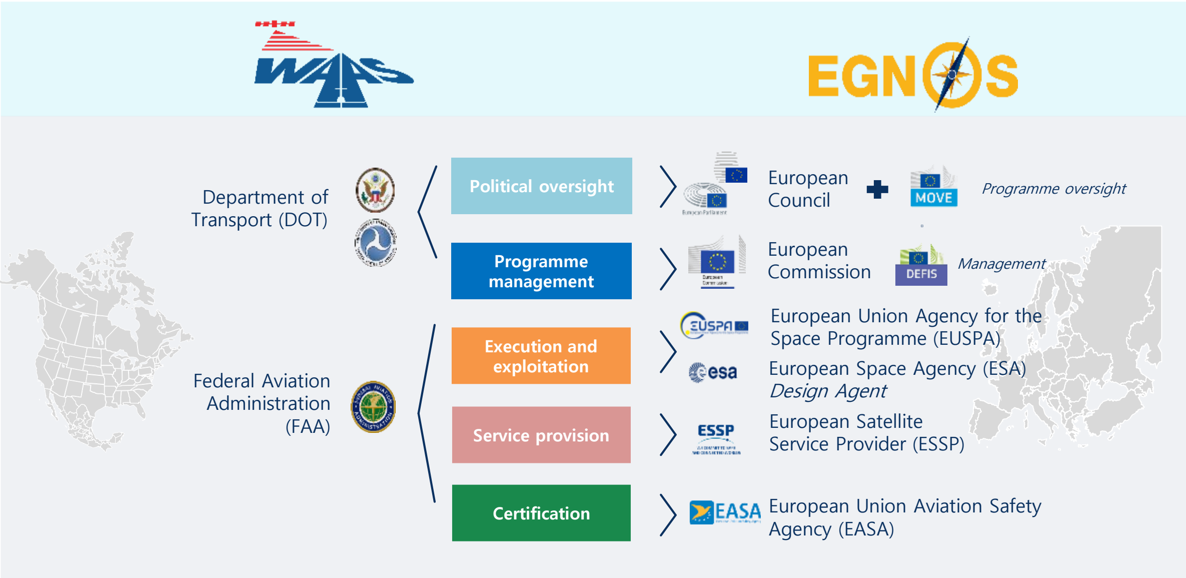


Figure 12: EGNOS and WAAS governance structure

1.3 Roles

The five layers of responsibility described above include different roles with internal connections among themselves. Identifying and defining the roles is the first step in developing an organizational and governance structure to facilitate the deployment of an SBAS system in Africa.

Table 3: Layers of responsibility and roles identification

Layers of responsibility	Roles
Political Oversight	**Oversighting Organization**: Organization in charge of supervising the programme and policy implementation at a continental level.
Programme Management	**SBAS Owner**: Owner of the system. In charge of providing strategic direction and ensuring the sustainability of the service.
	SBAS Programme Manager: Responsible for managing and coordinating all aspects of the SBAS Programme, from execution to market uptake.
Execution	**Design Agent**: Works as an intermediary between the Programme Manager and the Industry in the system development and deployment.
	Public/Private Companies: Supports the SBAS Programme Manager in the maintenance and development of the system, as well as providing support systems.

Service Provision	**SBAS Service Provider**: In charge of providing services based on SBAS, the Safety of Life Service (SoL) compliant with ICAO Standard and Recommended Practices (SARPS) as well as operating and maintaining the system. Some activities (i.e. system maintenance...) may be outsourced to other companies on a contract basis
	ANSPs and Other Users: The final users of SBAS, using the system data and services for different applications.
Certification	**National Civil Aviation Authorities:** In charge of providing regulation for the use of SBAS, ensuring its supervision and potential certification*
	Safety and Regulation Oversighting Organizations: Organizations in charge of promoting the highest common standards of safety, regulatory harmonisation and standardisation as well as involvement in certification activities*

*Matter of certification to be expanded upon in later sections

Note: A more detailed description of the specific responsibilities of these actors is included in the following section.

A high-level diagram showing the main functional relationships between the actors defined above is presented in Figure 13.

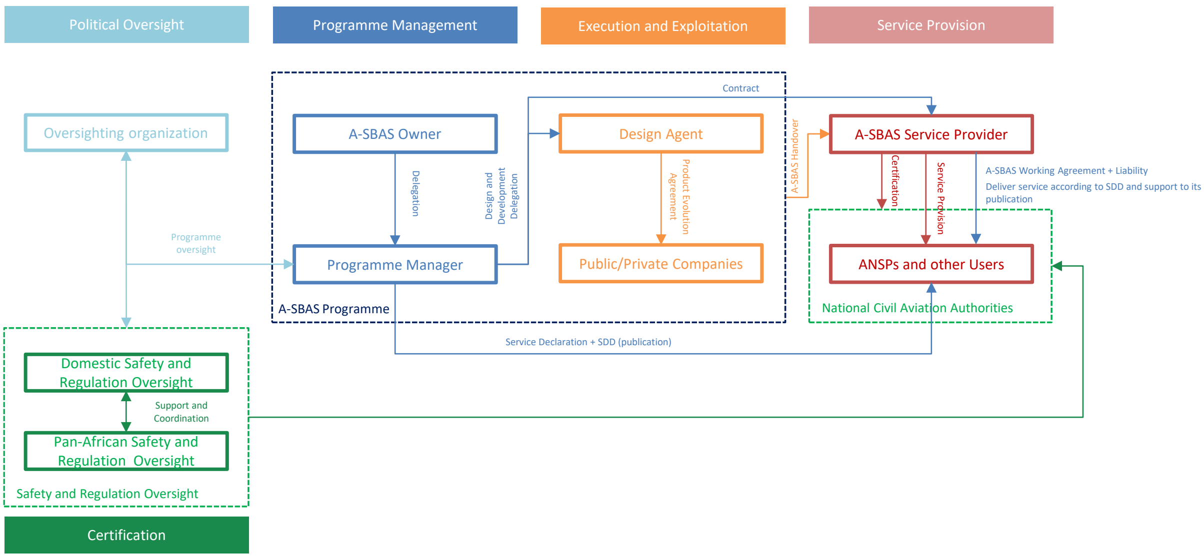


Figure 13: High-level relationships between SBAS actors

A full description of the responsibilities included for each role is now provided:

It is key to note that while in some SBAS programmes there is a fragmented organization in which individual entities cover each of these layers (Europe), in other cases many of these layers can be combined into a single entity with wider responsibilities (USA).

Oversighting Organization

- Overall programme supervision.
- Policy implementation at a continental level.
- Definition of strategic guidelines and programme priorities (types of services, targeted users, overall roadmap…).

Continental and Domestic Safety and Regulation Oversighting Organizations

- Formulate opinions on all policy matters related to the African aviation market.
- Take the necessary measures according to the applicable regulation/documentation
- Assist the SBAS Owner by preparing measures to be taken for the implementation of the required supporting Regulation/documentation.
- Conduct inspections and investigations as necessary, over the SBAS Service Provider.
- Carry out, on behalf of Member States, functions and tasks ascribed to them by applicable international aviation conventions, particularly the Chicago Convention.

SBAS Owner

- Ensure the financial and technical sustainability of the service.
- Be responsible for the SBAS programme and therefore approve both the evolution of the SBAS mission and the related roadmap.
- Authorize the declaration of the SoL (Safety of Life) service once the Readiness Review process is successfully passed.
- Delegate the exploitation and market development responsibilities to the SBAS Programme Manager.

SBAS Programme Manager

<u>Upstream</u>

- Overall responsibility for the design and development of the Af-SBAS system (can be delegated to the Design Agent)
- To lead the deployment and commissioning of the Systems, it will be involved in the preparation of sites for RIM Stations
- High level management of System/Service-related contracts
- To establish a contract with the Af-SBAS Service Provider.
- Review the SBAS Safety of Life Service Definition Document (SDD) proposal.
- Publish the SBAS SDD
- To support the service provision for the AF-SBAS Programme even in the pre-operative phase

- To set up the means to survey the service provider is complying with the Contract specifications, based on defined KPIs

Downstream

- Lead the development of institutional, economic and legislative studies or analyses to support the use of satellite navigation in the different domains.
- Support the exploitation of the Af-SBAS programme.
- Market uptake activities.

Note: In some cases, the SBAS owner and programme manager roles are combined into a single entity.

Design Agent

- Support the SBAS Programme Manager in the maintenance and development of the system.
- Act as an intermediary between the SBAS Programme Manager and the Industry.
- Place Product Evolution Agreement contracts between the SBAS Programme Manager and the Industry.

Note: In many cases, the SBAS Programme Manager and the Design Agent are the same entity

Public/Private Companies

- Maintain, develop and evolve the system (depending on the contract).
- Provide support systems in the deployment of the SBAS services, such as the GEOs or ground segment sites.

SBAS Service Provider

- Propose a draft Safety of Life Service Definition Document (SDD).
- Support the publication of the SDD.
- Manage the operations and maintenance of the SBAS system.
- Deliver the service according to the SDD terms and conditions.
- Provide the means to monitor the SBAS system.
- Provide the means to monitor the SBAS Safety of Life (SoL) Service.
- Establish Working Arrangements and Agreements with the ANSPs, Aerodrome Operators or any other organizations which are operationally responsible for SBAS-based procedures.
- To inform those organizations having established an Af-SBAS Working Agreement of predicted and unpredicted service deviations according to the defined procedures for the provision of Af-SBAS related services (as included in the Working Agreement)

- To provide the means to support the users (Air Operators, ANSPs, etc) in the introduction of the service
- To provide service performance reports and service coverage predictions
- Develop contractual arrangements for the maintenance of the SBAS ground infrastructure
- Develop contractual arrangements with telecommunication providers for the communication of all elements of the SBAS ground network infrastructure
- Delivery of NOTAM proposals regarding the future unavailability of the service for the assessment/confirmation of the ANSPs and publication by the AISPs

ANSPs

- ANSPs develop SBAS procedures and authorise the use of the SBAS Signal in Space in their airspace.

Aircraft or Air Operators

- The end users of the SBAS signal will be the domestic airspace users (including those represented in Africa by AFRAA and IATA) and international counterparts (i.e Airlines for Europe)

Other users

- Although SBAS in initially envisaged for aviation, as new SBAS services appear, the end users of the respective industries will play a role in the SBAS service provision scheme.

2. African Stakeholders Identification

Having identified the responsibilities mentioned within the African aviation ecosystem, the next step is to analyse the main African entities that could potentially be involved in SBAS deployment and operationalisation to later allocate them to the roles defined in the previous step.

2.1 Aviation Stakeholders

The African ecosystem is a complex scenario in which numerous actors coexist. In addition to ANSPs airspace users, and other entities more closely related to aviation operations, there are also political and regional entities with complex interactions among them. These entities bring together different countries within their scope of action, converging on common policies aimed at regional development. The identified African entities are illustrated in Figure 14.

Figure 14: African stakeholders

Once the main African aviation stakeholders are identified, it is necessary to analyse their functions and responsibilities to preliminarily assign roles within the organizational structure of the new SBAS system to be developed.

African Union

The African Union (AU) is a continental body consisting of the 55 member states that make up the countries of the African Continent.

Mandate and functions (related to aviation and space):

- Exercises political oversight over specialized agencies in aviation and space, ensuring alignment with continental goals and policies. It is also responsible for approving their budgets, thereby funding their activities. This oversight mechanism ensures that the strategic initiatives of these agencies, including the African Space Agency, are in line with the broader objectives of the AU for sustainable development and regional integration.

Strengths and maturity level:

- Political support for the growth and development of high technology sectors, including the space sector.
- Significant government support for the establishment of national and regional space programmes.
- Intra-continental partnerships fostering space science collaboration.
- Africa’s strategic and geographic locations suitable for astronomical and space physics facilities.
- Existing nodes of space expertise and in-situ capabilities.

RECs

The Regional Economic Communities (RECs) represent regional coalitions of African nations. These RECs have evolved independently and possess distinct functions and organizational frameworks. The primary goal of the RECs is to promote regional economic harmonization among member countries within their respective regions and as part of the broader African Economic Community (AEC).

Mandate and functions:

Objectives of the Plan of Action on Aviation Safety in Africa in which RECs are involved:

- Ensure implementation of States' Safety obligations.
- Establish and/or enhance effective civil aviation regulatory and oversight systems.
- Ensure the implementation of the African Civil Aviation Policy, Objectives and Strategies on Aviation Safety.
- Enhance Aviation Safety for sustainable Air Transport and Economic Development.

Strengths and maturity level:

- Political support for the growth and development of high technology sectors, including the space sector.
- Significant government support for the establishment of national and regional space programmes.
- Intra-continental partnerships fostering space science collaboration.
- Africa's strategic and geographic locations suitable for astronomical and space physics facilities.
- Existing nodes of space expertise and in-situ capabilities.

AFCAC

AFCAC (African Civil Aviation Commission) is the African Union's specialized agency for all civil aviation matters on the African continent and the Executing Agency of the Yamassoukro Decision (YD) and Single African Air Transport Market (SAATM), facilitating cooperation and coordination among African States towards the development of integrated and sustainable Air transport systems; and fostering the implementation of ICAO SARPs

Mandate and functions:

The main AFCAC functions are:

- Ensure seamless and close co-operation with the various RECs concerned with civil aviation matters, and their respective CAAs. Make concerted efforts towards the establishment of a single African Airspace.

- Coordinate the development and implementation of plans in the field of safety and aviation infrastructure.
- Promoting the development and harmonization of common rules and regulations for safety, security, environmental protection, fair competition…

Strengths and maturity level:

AFCAC has independently been promoting since 2007:

- Understanding of policy matters between its Member States and States in other parts of the world.
- Fostering the implementation of ICAO SARPs.
- Facilitating, coordinating and ensuring the successful implementation of the Yamoussoukro Decision.
- Coordinating civil aviation matters in Africa and cooperating with ICAO and all other relevant organizations and other bodies

SatNav-Africa Joint Programme Office (JPO)

SatNav-Africa JPO is a Pan-African specialized entity to support the implementation of seamless and sustainable satellite navigation services in all sectors, with aviation as the main driver.

Mandate and functions:

JPO is a Pan African specialized entity whose main functions are:

- Technical support and capacity building for regional and continental actors to accelerate the development of regional SBAS modules and the integration of SBAS into continental policies and planning.
- Supporting the adoption and use of GNSS services and the development of related applications and markets in Africa.

Strengths and maturity level:

- The Programme is contributing to economic and social development in Africa, in line with AU Space Policy and Strategy, as well as the Agenda 2063.
- The Programme is all Africa-inclusive and the main beneficiaries primarily from Aviation have been extended to non-aviation Communities.
- More than eleven (11) Regional Institutions including training Organisations have established working arrangements with JPO on GNSS/SBAS.
- The Programme assures GNSS/SBAS applications advocacy at regional and international levels (APIRG, IWG, etc.).

African Space Agency

The African Space Agency (AfSA) is a regional space institution created under the auspices of the African Union (AU) with the aim of fostering collaboration among AU member states in the realm of space policy.

Mandate and functions:

The main AfSA functions are:

- Implementing the African Space Policy and Strategy adopted by the AU Assembly.
- Promote and coordinate the implementation programmes and activities approved by the African Space Council.
- Support Member States and RECs in building their space programs and critical infrastructure and coordinate space efforts across the continents.
- Foster regional, intra-continental and international coordination and collaboration.

Strengths and maturity level:

AfSA was inaugurated in January 2023. When in full gear, it will count with the next strengths:

- Several stakeholders have lauded AfSA as the most important achievement for Africa in space, which will stop duplication and redundancy in space activities.
- AfSA is expected to properly implement the African space policy and strategy and achieve continental goals as the official space body tasked with coordinating and implementing African space policy.
- It will ensure optimal access to space-derived data, information, services, and products, as declared in its establishing statute.

National Space Agencies

Several African countries have established National Space Agencies or organizations responsible for space-related activities, research, and development.

Mandate and functions:

Among the functions of the African National space agencies, the most relevant are:

- Promote and boost the national space industry sector.
- Encourage research in the space domain and ensure the publication of scientific papers in the field.
- Promote domestic science, innovation, and technology related to space on both the African and international levels.

Strengths and maturity level:

The National African Space Agencies confirm their establishment due to the added value their activities bring to the economy and society of the continent:

- Collaborating with established public and private space technology giants institutes a network of experience and knowledge for African space agencies.
- This collaboration will ensure Africa is primed to become a competitor in the global space race.
- The development of their own space plans and technology allows these countries to maintain greater independence from foreign entities, enabling them to be more flexible in the utilization of their resources.

ASECNA

ASECNA (Agency for Aerial Navigation Safety in Africa and Madagascar) is an ANSP providing air navigation services in six FIRS encompassing the airspace of 17 countries in Africa

Mandate and functions:

ASECNA's mission is to ensuring safety in air navigation in the airspace it manages. Among the functions of ASECNA:

- Proving en-route ANS in the airspace
- Providing aerodrome with air traffic, approach and aerodrome services
- Managing schools and offering courses to solve challenges of civil aviation

Strengths and maturity level:

Related to SBAS, ASECNA is currently leading the development of ANGA (Augmented Navigation for Africa). This programme has already developed an operational testbed to showcase its advancements in SBAS Programme and drive adoption and acceptance of this technology in the African continent. This has paved the way towards ANGA's SBAS initial non-operational services, which been broadcasted effectively on L1 band since September 2020, demonstrating its capabilities in setting up an initial SBAS Programme.

Full information on the advancements of ANGA will be provided in *Task 1.2 Technology Transfer Assessment*

Airspace users (i.e IATA and AFRAA)

The African Airlines Association (AFRAA) is the leading trade association of airlines which hail from the nations of the African Union, comprising 50 airlines representing 85% of international traffic in the continent.

The International Air Transport Association (IATA) is the trade association for the world's airlines, representing some 300 members.

Mandate and functions:

Among the functions of AFRAA and IATA:

- Enhance the visibility, reputation and influence of African airlines in the global industry

- Push for sustainable air transport
- Advocate for the reduction of costs of air transport services
- Lobby for market access to increase revenues and enhance connectivity

Strengths and maturity level:

AFRAA and IATA are well-established organisations that aim to serve the interests of airlines in Africa.

They will be particularly involved in the uptake of SBAS in the continent as they will need to state their position on SBAS services and equipage, as well as influence certain aspects such as the financing model. In this regard, IATA and AFRAA have already expressed their opinion during Phase I of the study, supporting SBAS implementation if charges are not imposed on airspace users not benefitting for the services.

Private industry

A detailed assessment of the industrial landscape is provided in Task 2 of this Phase 2 of the SBAS CBA project.

2.2 Non-Aviation Users

Alongside the large number of actors that make up the African aviation scene, numerous users from other markets may have a potential interest in the services that the SBAS system allows to develop.

While aviation is the primary sector in which SBAS technology can serve as an engine for economic growth and safety, it is not the only one. The maritime, road, railway, and agricultural markets are other sectors that can benefit from this technology in Africa.

Figure 15: Possible Af-SBAS Users by markets – non-exhaustive

As can be extracted, SBAS is not limited to aviation but has a wide range of applications in diverse industries and sectors where accurate positioning, timing, and navigation are essential. Its benefits extend to improving safety, efficiency, and productivity across various non-aviation fields.

3. Possible SBAS Configuration Description and Benchmark

3.1 SBAS Models Description

For the Af-SBAS, an institutional model must be developed, allocating the identified responsibilities between the African stakeholders. This may include the creation of an **African SBAS Organisation,** which could take various forms depending on three layers of decision: the number of entities, the ownership model, and the centralization model.

3.1.1 Number of Entities

In general, there are three key roles that may or may not fall under the same entity: the SBAS Owner, the SBAS Programme Manager, and the Service Provider.

From this perspective, three scenarios can be considered:

- **Single Organization:** The three roles fall under a unique organization in charge of all the system's lifecycle: Planning, designing, developing, implementing, and serving provision phases.
- **Double Organization:** Owner and the programme manager are the same entity, with an independent service provider
- **Triple organization:** In this case, the three roles fall under different organizations, completely differentiating their activities.

3.1.2 Ownership Model

Three models can be defined regarding the SBAS ownership model:

- **Public African Organization:** Full African public ownership of the SBAS system.
- **Private organization:** A privately funded company with an interest in developing an SBAS system.
- **Public-Private Partnership:** A collaborative arrangement between a government or public sector entity and a private sector company or consortium to leverage the strengths and resources of both sectors.

3.1.3 Centralization Model

Regarding the number of SBAS Programmes, some models can be extracted by identifying where and who will be providing the SBAS services along its coverage area:

- **Continental:** One single SBAS programme for the entire African continent.
- **Regional:** Multiple independent SBAS programmes at the regional level (i.e., linked to countries, RECs…) with no shared functions (i.e., oversight…).

- **Hybrid:** Possibility of multiple SBAS programmes at regional levels with certain shared functions or elements (oversight, roadmap, strategic direction, regulation…).

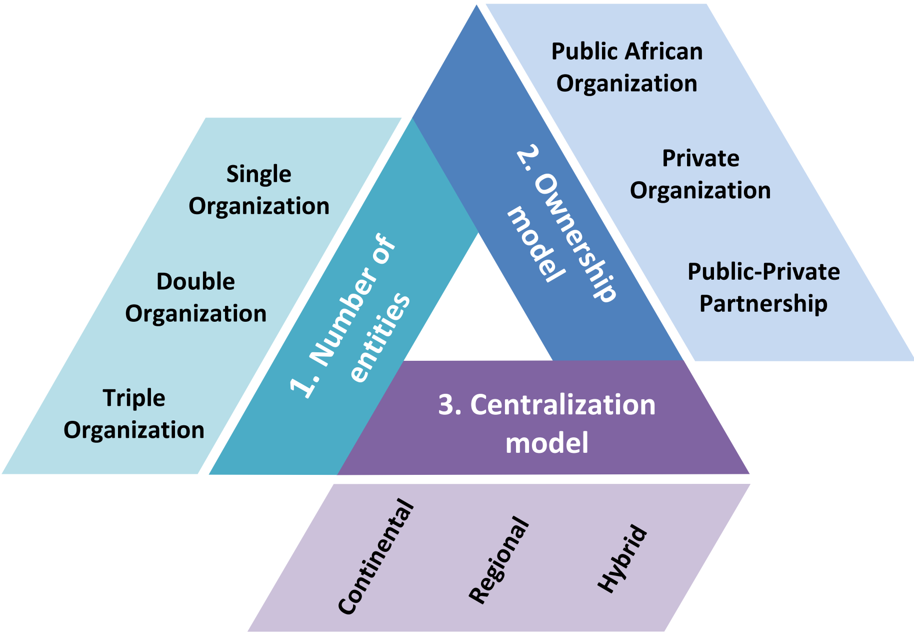


Figure 16: SBAS Model Possibilities Diagram

3.2 International Benchmark of SBAS models

Several countries have implemented their own Satellite-Based Augmentation System. All these systems comply with a common global standard and are therefore compatible and interoperable.

The SBAS programmes analysed are WAAS (USA), EGNOS (EU), SouthPan (Australia and New Zealand), KASS (South Korea), MSAS (Japan), and GAGAN (India). Their illustrative service areas are presented in Figure 17.

Each of them follows a different governance and organizational model, which makes their analysis interesting to draw insights, lessons learnt and best practices to apply to the case of African SBAS.

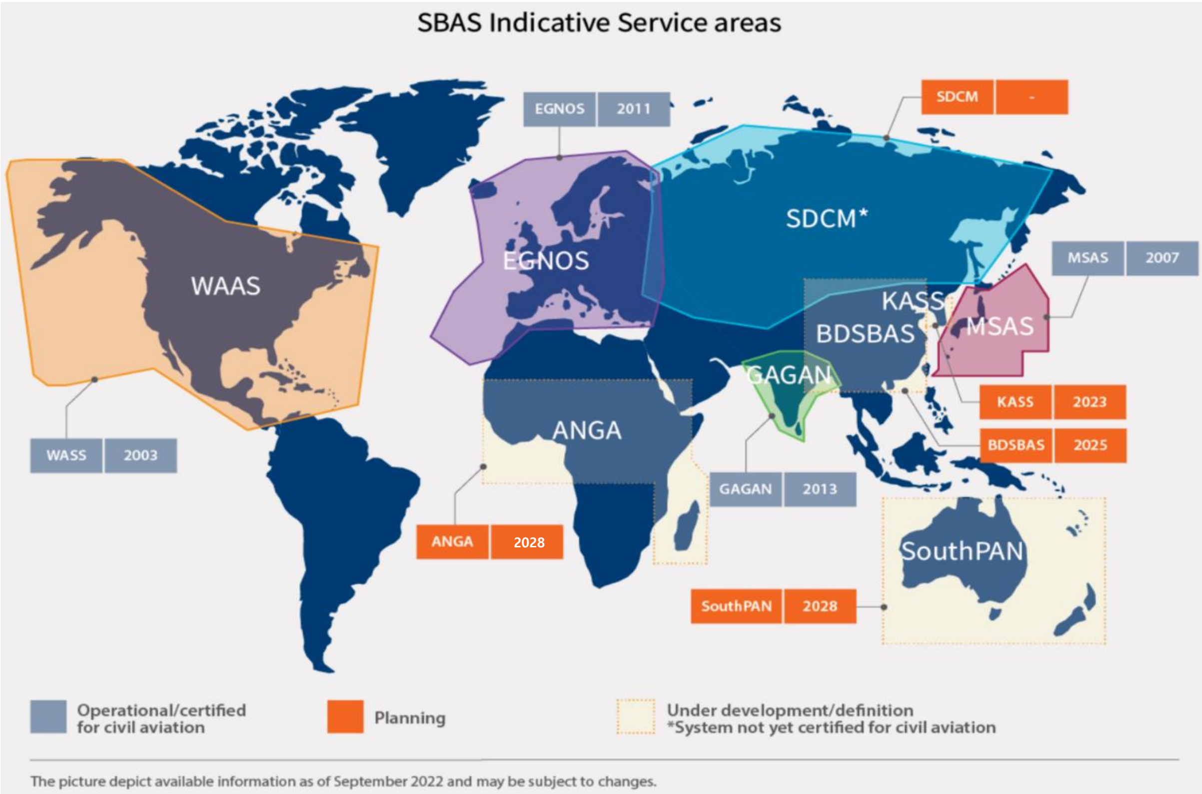


Figure 17: SBAS Systems around the world: Source: ESA

An analysis of the centralisation and ownership models as well as on the number of entities has been performed for each of these programmes, illustrated in Figure 18.

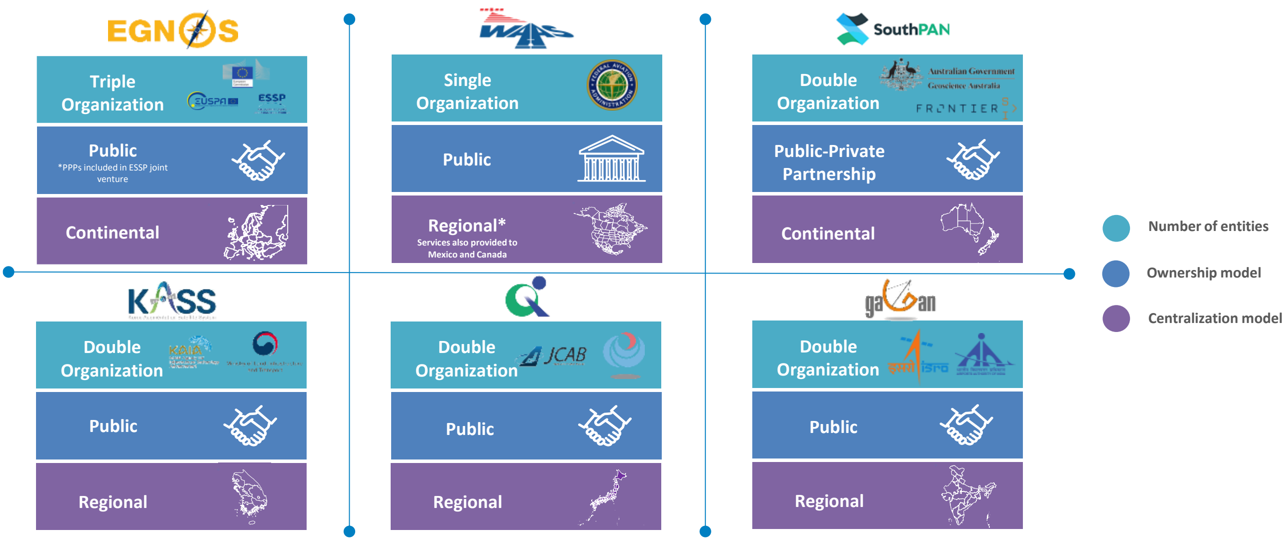


Figure 18: SBAS institutional models around the world

Note: China also has shown advances in BeiDou as well as their SBAS programme (BDSBAS – SNAS, nearing entry into operations with the participation of China Satellite Navigation Office

(CSNO), Civil Aviation Administration of China (CAAC), and China Satellite Navigation Project Center as well as the Industry partner Novatel Hexagon.

It is possible to extract some trends from the analysis of these programmes:

Regarding the **number of entities**, various models exist around the world, the most widely used being the double organisation, in which the roles of owner and manager are merged and the service provider is usually separated from the other entity. Europe and the USA present completely different models, in the case of the WAAS programme, all functions are concentrated within the FAA while in Europe, the EU Commission, EUSPA and ESSP (as well as ESA) each play their role within the programme. There is therefore no clear-cut model used throughout the world.

Concerning the **ownership model**, the clear trend followed worldwide is public ownership of the SBAS programme and system. The only outlier is SouthPan, developed by Australia and New Zealand, which was created under a Public-Private-Partnership, allowing to share investment and associated risks. It is worth mentioning however, that in the case of SouthPan, the key driver of the programme is not aviation and Safety-of-Life service but rather other applications, with possibly more commercial potential, incentivising the presence of private entities

Finally, concerning the **centralization** model, there are two clear cases at the international level: continental and regional. The different scenarios are closely related to the country or group of countries that decided to implement the system. For example, the EU provides service to all member countries (and neighbouring ones through working agreements or bilateral agreements between the EU and the respective state). Additionally, SouthPan can also be considered a continental solution as it was implemented by two different States, working in collaboration. In the case of countries like India, Korea or Japan, the SBAS service is limited to their territory. An interesting case is WAAS, which was developed solely by the USA but provides services to other countries in the coverage region through bilateral agreements.

3.3 The European case

As part of the international benchmark, special consideration should be taken to explain the figure of the European service provider scheme: ESSP SAS, an interesting concept from which numerous insights can be learnt.

The European Satellite Services Provider (ESSP) is the EGNOS Services Provider within Europe, certified according to the Single European Sky (SES) regulation as an Air Navigation Service Provider (ANSP). ESSP is a European private joint company under French law, integrated by 7 shareholders. Its establishment was expressly made for this purpose as a joint venture of several of the most important ANSPs in Europe (DFS, DSNA, ENAV, Enaire, NATS, Skyguide and Nav Portugal), although nowadays it performs other tasks, such as consultancy for other interested companies and entities in the services they master.

Figure 19: ESSP's shareholders and locations

The service provision scheme is as presented in Figure 20:

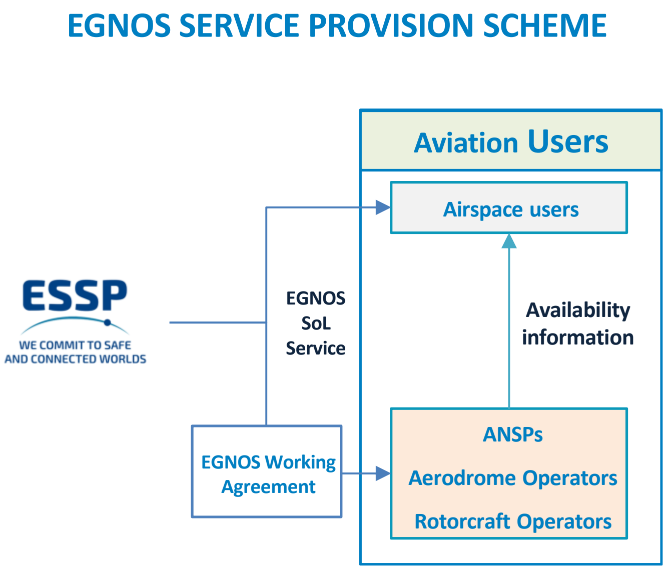


Figure 20: EGNOS Service Provision Scheme

Service provision is conducted according to a contract with the SBAS Programme Manager (EUSPA)

Another key aspect of the EU model is regulation and certification. In Europe, the SBAS service is certified by a single authority at European level (EASA) under the Single European Sky EASA Basic Regulation.

In the case of EGNOS, the initial certification before EASA took the role of pan-European Competent Authority was done by French NSA but with the support of the ENSAC (EGNOS National Supervisory Authority Committee), composed of several other Authorities. The leading role of the French NSA was coming from the fact that ESSP SAS is a service provider whose main place of operation is in France.

Matters related to liability, working agreements, and other activities performed by the SBAS Provider in Europe are not included in this section but rather will serve as the foundation of the service provision and regulatory sections in the selected SBAS model description (Section 6.2 and 6.5)

4. Model Selection Criteria

After determining the possible organisational structures that the African SBAS Programme could follow and identifying the main aviation stakeholders in the African landscape, the door is opened to the analysis of which of these models will fit better into the current scenario.

Figure 21: Evaluation criteria for model selection

The assessment will be performed with a multi-criteria analysis combining various criteria to have a holistic assessment covering all possible implications of the SBAS organisational and institutional model.

Four main categories of criteria have been defined, which will be used to evaluate the three layers of SBAS models: ownership, centralisation, and number of entities.

Financial: Evaluates the economic feasibility of the SBAS programme and organisation along its lifecycle, from set up to operation. The parameters evaluated are:

- Funding capability: Assesses the capacity of the model to raise the required amount of capital to set up the SBAS service.
- Long-term sustainability: Evaluates the longer-term economic sustainability of the programme, assessing the model's self-sufficiency.
- Cost-efficiency: Describes the possible duplicities in terms of human and infrastructure resources.

Governance and collaboration: Assesses the potential effectiveness of the governance framework, outlining potential impacts on decision-making processes, roles, and responsibilities. The parameters evaluated are:

- African institutional control: Determines the level of control and influence the African states would have over the SBAS system in each model.
- Socio-Political acceptance: Assesses the level of acceptance and support from governments, aviation authorities, and other stakeholders.
- Decision-Making Processes: Assesses the decision-making mechanisms and consensus-building processes.

Regulatory and legal: Evaluate the regulatory and legal framework regarding all the programme dimensions. The parameters evaluated are:

- Regulatory coordination/standardization: Evaluates whether the organisational model ensures that the SBAS service is subject to a certain level of common regulations and standards across the continent, in compliance with international standards, as well as the possibility of a common certification process.
- Caters to regional needs: Evaluates whether the SBAS model ensures that African regions can develop tailored regulations to meet their needs
- Legislation capacity: Identifies the model's capabilities of proposing and enforcing the necessary regulations for the development of the project.

Operational and service: Assesses the operational aspects that involve providing the SBAS services considering the user necessities and the African context. The parameters evaluated are:

- Time and complexity of implementation (time-to-market): Assesses whether the organizational models offer any advantages or drawbacks in terms of time-to-implementation
- Technical expertise: Evaluates the technical capabilities and expertise of the organizational model to operate and maintain the SBAS system and its infrastructure.

All aspects outlined in the criteria will be assessed to obtain the model that best fits the project's requirements.

5. Multicriteria Analysis

After setting the criteria for evaluating each of the models, it's time to conduct a comprehensive analysis of each model.

5.1 Centralization Model

In the centralization model, three possibilities are considered: Continental, Regional and Hybrid.

	Continental Model	
Criteria	Rationalization	Evaluation
Financial	• Lower setup costs and operational expenses, as a single system will be employed across all of Africa, implying less duplicity in terms of ground and space infrastructure as well as human resources. • A pan-African programme may have a higher probability of being funded (partly) by international or multilateral institutions.	
Governance and collaboration	• Given the sovereignty of the African nations and the varied levels of regional development, there might be resistance to yielding control to a central authority. • Having a single coordinating entity (such as the African Union) can help streamline decision-making and help the programme achieve the public interests of African society.	
Regulatory and Legal	• A one-size-fits-all approach may not cater to the specific needs of some African regions, impacting aviation needs. • The African Union (AU) does not have legislative powers like the European Union (EU), so it can only make proposals to the member states. It is up to the member states to implement these proposals into their legislation.	
Service and operations	• Possibility to combine the efforts of African stakeholders at a continental level, meaning enhanced technological capabilities and optimization of the infrastructure.	

Table 4: Continental model analysis

	Regional Model	
Criteria	**Rationalization**	**Evaluation**
Financial	• Higher setup costs and operational expenses, as there will be higher levels of duplicity in terms of infrastructure and personnel. • Less probability of international or multilateral institutions funding several SBAS programs in parallel.	
Governance and collaboration	• Some countries may have less resistance to the programme as control is not yielded to a central entity. • A lack of a centralised entity may imply difficulties in coordination between programmes, as each may have different strategic objectives and roadmap.	
Regulatory and Legal	• This model allows individual countries to develop their own SBAS regulations that cater to local needs. • This model does not ensure that all users receive the same level of service under the same regulation in Africa, causing continuity problems. • Some Regional Economic Communities (RECs) or RSOOs have the ability to generate legislation that applies to all their member states, facilitating implementation.	
Service and operations	• Lower technological development and infrastructure capabilities. • The operation's maintenance can be threatened by a lack of technological resources. • Ensuring consistent service levels and compatibility between regional systems can be complex.	

Table 5: Regional Model analysis

	Hybrid Model	
Criteria	**Rationalization**	**Evaluation**
Financial	• Certain cost duplications may arise, but there will be higher economies of scale due to sharing common elements (policy-making, regulation, market development…)	

Hybrid Model		
Criteria	**Rationalization**	**Evaluation**
Governance and collaboration	• The existence of a central agency pushing for the overall benefit of African society and acting as a point of coordination for the different programmes. • Leverage the existence of regional units (RECs) with strong socio-political relationships and prior collaboration agreements on various aspects (commercial, regulatory...) with their member states.	
Regulatory and Legal	• Existence of a centralised entity for policy and standards oversight. • It allows individual countries and regional blocks to develop their own SBAS regulations that cater to local needs if necessary, leveraging on the existence of RECs and RSOOs.	
Service and operations	• Higher possibility for technological development and infrastructure capabilities. • Possibility to combine the efforts of African stakeholders at a continental and regional level. • A challenge of the hybrid model is that several SBAS programmes derive in multiple signals and service areas, demanding a need for coordination between stakeholders to ensure interoperability and seamless service for airspace users. This can be mitigated with consultation when defining the SDDs and RIMS placement	

Table 6: Hybrid Model analysis

This analysis can be summarized in Table 7:

		Centralization Model			
Models	**Financial**	**Governance and Collaboration**	**Regulatory and Legal**	**Service and operations**	**Selection**
Continental					
Regional					

Hybrid					✓

Table 7: Centralization Model Analysis Conclusions

Comparing the results of the multicriteria analysis, recommended solution is to opt for a **hybrid model**, presenting the best score in terms of governance, regulation and service & operation, with the drawback of less financial viability due to increased cost duplicities.

5.2 Number of Entities

The analysis of the number of entities will include three possibilities.

The first, single organization, is an organization that combines the roles of owner, SBAS manager, and service provider.

The double organization considers the existence of two entities sharing roles, either as owner and manager or as manager and service provider, with the other entity solely being a service provider or owner, respectively.

Finally, the triple organization separates the roles into three independent entities.

Single Organization		
Criteria	**Rationalization**	**Evaluation**
Financial	• Lower costs due to the establishment of a single entity that consolidates all roles and responsibilities.	
Governance and collaboration	• All roles fall under the same entity, making the coordination of activities, responsibilities, and resources simpler and more efficient.	
Regulatory and Legal	• A single entity will be accountable to multiple oversight committees and comply with a range of legislative and executive standards, which can create a complex regulatory environment.	

Service and operations	• A single entity will need to concentrate all programme functions, combining financial, management, exploitation and service provision responsibilities. In the case of Africa there is no entity at a continental level currently possessing these capabilities and creating this institution from scratch is considered very challenged from an operationalisation standpoint.	

Table 8: Simple Organization analysis

Double Organization		
Criteria	**Rationalization**	**Evaluation**
Financial	• The separation of responsibilities into two entities generates higher costs, including duplicities.	
Governance and collaboration	• Governance becomes more complicated due to the need for coordination between two entities, whose roles and relationships must be well-defined. • The previous existence of entities that can carry the defined responsibilities must be considered.	
Regulatory and Legal	• Establishing multiple entities helps avoid the concentration of power. • Achieving a harmonized provision of services necessitates a regulatory framework that clearly defines the responsibilities of each entity.	
Service and operations	• The technical expertise of the entities is enhanced by the ability to separate activities, allowing each one to specialize in a specific area.	

Table 9: Double Organization Analysis

Triple Organization		
Criteria	**Rationalization**	**Evaluation**
Financial	• The separation of responsibilities into three entities generates higher costs, including duplicities. • Ownership and management could easily coexist under the same entity.	
Governance and collaboration	• All roles fall on different entities. • Governance becomes more complicated due to the need for coordination between three entities, whose liabilities must be well-defined. • The previous existence of entities that can bear the defined responsibilities must be considered.	
Regulatory and Legal	• Establishing multiple entities helps avoid the concentration of power. • Achieving a harmonized provision of services necessitates a regulatory framework that clearly defines the responsibilities of each entity.	
Service and operations	• The technical expertise of the entities is enhanced by the ability to separate activities, allowing each one to specialize in a specific area.	

Table 10: Triple Organization analysis

This analysis can be summarized in Table 11:

Number of Entities Model					
Models	**Financial**	**Governance and Collaboration**	**Regulatory and Legal**	**Service and Operations**	**Selection**
Single					✓
Double					✓

Triple					

Table 11: Number of Entities Model Analysis Conclusions

Comparing the results of the multicriteria analysis, the option that best aligns with them is the double entity model. In this case, the owner and the programme manager will fall upon the same entity, being the service provider an independent company.

Economic considerations must be considered, as the costs associated with the creation and operation of two entities will always be higher than for one. On the other hand, in terms of governance and collaboration, coordination and responsibilities between both must be perfectly defined to avoid inefficiencies, although specialization in each of the activities allows for better performance if it is fulfilled.

5.3 Ownership Model

In the ownership model, three possibilities will be considered: Public African Organization, Private Organization and Public-Private Partnership Organization.

	Public African Organization	
Criteria	**Rationalization**	**Evaluation**
Financial	• Funded by public funds from African States. • The funding will be contingent on the states' current financial capacities (with funding from SBAS having to "compete" with all other national initiatives) and on development plans / grants originating from other regions. This could at some point compromise the continuous funding of the SBAS Programme if financial difficulties arise in the member states	
Governance and collaboration	• African countries will have control over the development and operation of the system, promoting relationships with other governments, Civil Aviation Authorities (CAAs), and supporting the creation of synergies.	
Regulatory and Legal	• No clear negative regulatory or legal implications.	

Service and operations	• The technical capabilities of a completely public entity would be entrusted to the technological agencies of the relevant countries, assuming responsibilities that may be beyond their technical experience.	

Table 12: Public African Organization analysis

Private Organization		
Criteria	**Rationalization**	**Evaluation**
Financial	• Private companies can have large amounts of capital for upfront investment. • Regarding the longer-term sustainability of the SBAS system, the limited commercial profits in the short term may involve financial risks that are too high for a private company, compromising sustainability.	
Governance and collaboration	• African countries will not have control over the system.	
Regulatory and Legal	• The regulatory framework would need to ensure that private sector involvement does not compromise the public service mandate of SBAS systems.	
Service and operations	• The private company will have significant technical capabilities to deploy and operate the system.	

Table 13: Private Organization Analysis

	Public-Private Partnership Organization	
Criteria	**Rationalization**	**Evaluation**
Financial	• The private sector can mobilise additional financial resources alleviating the public sector's burden. • The private sector partner will expect compensation for accepting the involved risks and may be limited profitability due to the nature of the service, although this can be mitigated with a long-term contract.	
Governance and collaboration	• African states will have considerable control over the deployment and operation of the system as well as its strategic direction and roadmap • The allocation and monitoring of shared responsibilities in the governance of PPPs can be complex and lead to challenges in management and dispute resolution. • PPPs involve complex negotiations and detailed contracts to define the roles, responsibilities, and expectations of both parties, which can be time-consuming and require significant legal and financial expertise.	
Regulatory and Legal	• The regulatory framework would need to ensure that private sector involvement does not compromise the public service mandate of SBAS systems.	
Service and operations	• The private sector often brings innovation, efficiency, and expertise in managing complex projects, which can be beneficial in deploying and operating SBAS technologies. • With the private sector's focus on customer service and competitiveness, SBAS services might see improvements in quality and innovation. • Risks associated with the SBAS service provision (such as technological risks or demand uncertainty) can be shared between the public and private partners, potentially leading to better risk management.	

Table 14: Public-Private Organization Analysis

This analysis can be summarized in Table 15:

	Ownership Model				
Models	Finance	Governance and Collaboration	Regulatory and Legal	Service and Operational	Selection
Public African Organization					
Private Organization					
Public-Private Partnership Organization					

Table 15: Ownership Model Analysis Conclusions

Comparing the results of the multicriteria analysis, the preferred model is the public African organization. Even though financial difficulties could arise, it is believed that the involvement of a private party and its search for profit could pose concerns in the programme's governance and regulatory framework.

5.4 Model selection and justification

Combining all three decision layers, a recommended solution for African SBAS implies a hybrid centralisation model (central coordination entity and possibility of multiple SBAS programmes), fully owned by public African Stakeholders, with each individual programme having freedom to organise their internal operations. Nevertheless, on this point, opting for a single or dual internal organisation is recommended.

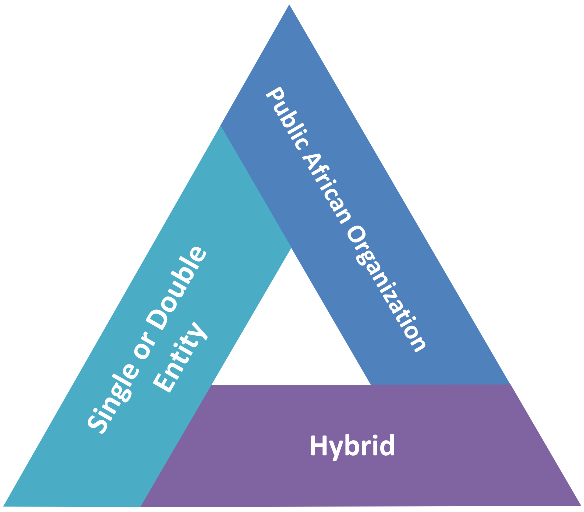


Figure 22: Af-SBAS Model Selection

- **Hybrid Centralisation Model**: Implementing a hybrid centralization model has numerous benefits that can lead to the success of the SBAS initiatives in Africa. The existence of a central entity providing a common Policy as well as certain guidance over the SBAS roadmap will ensure coordination over the different initiatives as well as a unified regulatory framework and service levels. However, this hybrid model also leverages the benefits of decentralization as it may bring about less resistance from countries and exploit the legislative powers of the RECs, who can enforce the regulation.

  This hybrid model entails that a central coordination entity providing political oversight with certain decision-making responsibilities is considered a key success factor for the SBAS initiative.

- **Number of entities:** The recommendation is for each SBAS programme to have either a single or dual organizational model

  - Single: This model involves the creation of a single entity concentrating all functions, avoiding resource duplicities and offering streamlined governance, as all responsibilities fall within the same organization. However, this organization will have to concentrate several functions of very distinct typology (management, system development, service provision, market development…) making it difficult to implement if a single entity doesn't combine all this expertise.

  - Double: This model involves the separation of roles and responsibilities between two distinct entities; one acting as the owner and programme manager, and the other serving as the service provider. This approach is designed to introduce a level of separation and specialization in the management and operation of the SBAS while avoiding large cost duplicities in a triple organisation.

- **Ownership model**: The recommendation is to opt for a fully public African SBAS
  - Public African Organization: it implies that a government or a publicly owned entity in Africa has the responsibility for owning and managing the SBAS program. In this scenario, the organization assumes a central role in the strategic planning, implementation, and overall governance of the SBAS.

    It's important to note that, in this model, the public African organization may choose to work with external partners, contractors, or service providers for specific functions, such as technical operation, maintenance, or user support. The organization retains overall ownership and management control, emphasizing the public sector's role in providing critical infrastructure for navigation and positioning services.

It is understood that an organization based on a Public-Private Partnership has numerous benefits, as it aims to leverage the strengths of both sectors to design, deploy, and operate an effective and sustainable SBAS infrastructure, leveraging on the expertise of the private sector. Additionally, the private party would help finance the program, alleviating the African Member States. However, the effectiveness of the PPP model relies on a carefully designed regulatory framework that ensures a balance between public service interests and private economic considerations A major blocking point as of now is the lack of economic incentive for the private party, as initial SBAS services, as will be explained in the next section, are expected to be free for the users, as agreed in the outputs of Phase I of the Continental SBAS CBA Study. A PPP is therefore currently not considered, although it could remain an interesting possibility in the future for successive SBAS programs or evolutions

6. Chosen SBAS Model implementation

Following the model selection, it is now crucial to elaborate on the approach to its realization. This deep dive into the selected alternative will be performed on organisational, service provision, economic and regulatory levels

6.1 Organizational structure and governance

The overall African SBAS governance and organisation is depicted below:

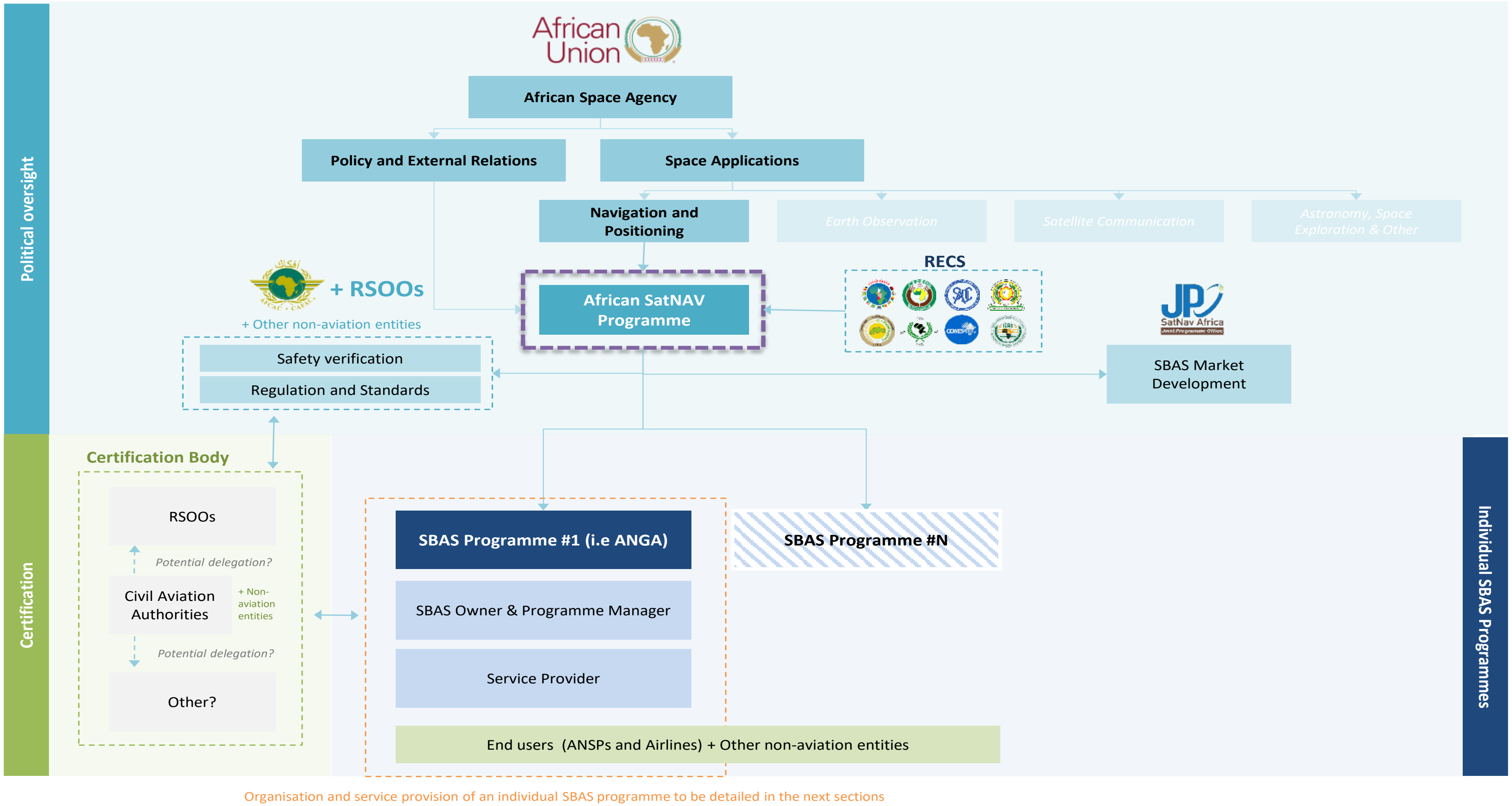


Figure 23: Selected SBAS institutional and organisational model

The proposed solution involves an "African SatNAV Programme", at a continental level, leveraging the approved structure of the African Space Agency and the Outer Space Strategy, which revolves around four pillars: (i) Navigation and Positioning, (ii) Earth Observation, (iii) Satellite Communications and (iv) Astronomy and Space Exploration.

The African SatNAV Programme would therefore be embedded into the Navigation and Positioning pillar and would contain all activities regarding SBAS in Africa. This African SatNAV Programme would be led and coordinated by the African Space Agency and receive contributions from the RECs, AFCAC, the RSOOs as well as the SatNAV Africa JPO, as illustrated above. The main responsibilities of each of the actors are included below:

African Union

The African Union (AU) would exercise political oversight over specialized agencies in aviation and space, in this case namely AfSA, ensuring alignment with continental goals and policies. It would also be responsible for approving their budgets, thereby funding their activities. This oversight mechanism ensures that the strategic initiatives of these agencies are in line with the broader objectives of the AU for sustainable development and regional integration.

African Space Agency

The African Space Agency, established as an African Union organ, is tasked with promoting and coordinating the development and utilization of space science and technology for Africa's benefit. Its main objectives are to implement the African Space Policy and Strategy, leveraging space technologies for sustainable development. Within the scope of the African SatNAV Programme, its responsibilities would include:

- Overall programme supervision and oversight
- Policy and strategic guideline definition at the continental level (types of services, targeted users, overall roadmap…)
- Ensuring SBAS development is aligned with African priorities (Agenda 2063, SAATM…)
- Facilitating cooperation between different regions with the RECs

AFCAC:

Its role within the African SatNAV Programme would revolve around the unification of SBAS standards and regulations across the continent to maintain compliance with international standards set by entities such as the International Civil Aviation Organization (ICAO). It is still pertinent that the Standards and Recommended Practices set by ICAO are transposed into law in the respective Member States. AFCAC, with the collaboration of the RSOOs, as will be detailed below, could play a role in developing standardised regulatory texts for adoption by Member States ensuring the required harmonisation. This regulatory harmonisation towards technical and operational regulations shall ensure consistency and interoperability between neighbouring airspace.

Regional Safety Oversight Offices (RSOOs)

These RSOOs, together with AFCAC would be responsible for regulatory harmonisation through the development of the model legislation pursuant to the relevant ICAO Annexes. These would liaise between AFCAC and local civil aviation authorities (CAAs), ensuring that the model laws are transposed into the respective member States' legislation and SBAS services are effectively implemented at a regional level while adhering to the continental framework. Important to note is that the RSOOs in Africa are in fact specialised aviation Agencies/Institutions responsible for aviation safety and security matters, save for perhaps BAGASOO which is a creature of its own Statute, and does not derive its establishment from a Treaty or Agreement of a REC, as is the case with EAC CASSOA and SASO.

In the cases of non-aviation applications requiring a regulatory framework, other entities would need to be identified.

Regional Economic Communities (RECs) The proposed roles of the RECs could be as follows

- Act as a liaison between the African SBAS Programme and the Individual initiatives
- Contributing to the African SBAS Programme's policies
- Help impose binding policies and laws in their areas of influence

ICAO PIRGs: Advisory and engagement in the institutionalisation, planning and implementation of SBAS technology in Africa

SatNAV for Africa JPO:

The Short-Term Experts (STEs) believe that given SatNAV Africa JPO's existing capabilities, they could take up the role of SBAS market development at a continental level. This would entail the following responsibilities.

- **Promotion:** Implementation of awareness campaigns targeting key industries (workshops, webinars, informational materials) to educate users on the benefits of SBAS in their operations. Other promotion tasks could include:
  - **Industry forums:** Establish forums dedicated to specific industries where users can exchange experiences, discuss challenges, and share best practices related to SBAS implementation.
  - **Collaborative demonstrations:** Promote and organise joint demonstrations of SBAS applications in collaboration, presenting tangible examples of how SBAS can provide benefits
- **Market monitoring and analysis:** Lead the development of institutional, legislative or economic studies to support the use of satellite navigation (i.e., market assessments…)
- **Capacity building:** Coordinate regional workshops and training programs tailored to the specific requirements of each industry.

- **User adoption support:** Organise user adoption programmes, aiding end users to take profit from SBAS technology

This would allow to reduce duplicities between the potential programmes, as the market development activities would be transversal to all of them.

Below this first political layer, there would be a number of individual SBAS programmes (at least two are considered necessary to cover the entirety of the African continent), with great levels of independence albeit subject to the general policies set out by the African SBAS Programme.

These individual SBAS programmes would be free to implement their desired internal organisational, although single or dual-entity approaches are recommended. In the case of a **dual organisation,** the responsibilities would be as follows:

SBAS Owner + Programme Manager: *Entity to be decided depending on Programme*

- Ensure the financial and technical sustainability of the service.
- Be responsible for the individual SBAS programme and therefore approve both the evolution of the SBAS mission and the related roadmap
- Place contracts (Product Evolution Agreements) with the industry for the system development and maintenance
- To establish a contract with the SBAS Service Provider.
- Review the SBAS Safety of Life Service Definition Document proposal and publish the SBAS SDD as proposed by the SBAS Service Provider
- Authorize the declaration of the SoL (Safety of Life) service once the Readiness Review process is successfully passed.
- Ensure the certification of the systems' components guaranteeing their readiness for the intended Service

SBAS Service Provider: *Entity to be decided depending on Programme*

- Propose a draft Safety of Life Service Definition Document (SDD).
- Support the publication of the SDD.
- Manage the operations and maintenance of the SBAS system.
- Deliver the service according to the SDD terms and conditions.
- Provide the means to monitor the SBAS system and service.
- Provide the means to monitor the SBAS Safety of Life (SoL) Service.
- Establish Working Arrangements and Agreements with the ANSPs, Aerodrome Operators or any other organizations which are operationally responsible for SBAS-based procedures.

In the case of a **single organisation**, this entity would combine all responsibilities detailed above.

Certification body:

Entity responsible for certifying the SBAS service Provider and system. Typically, the national Civil Aviation Authority would oversee this certification process. However, to streamline the certification process, the CAAs could delegate this function to another entity (either existing or a body of new creation), which could certify services in several states. For example, a Level 3 RSOO would be responsible for granting such certification, always under the oversight of the national CAA.

Another potential model for Africa can be extracted from the case of Europe. As of today, EASA has the role of a pan-European Authority in charge of EGNOS certification (level 3 RSOO). However, the initial certification before EASA was done by the French NSA **with the support of ENSAC (EGNOS National Supervisory Authority Committee),** composed of several other authorities, who delegated and oversaw these certification functions. Applying this model to Africa would entail designating and empowering this certification entity and setting up a committee formed of National CAAs in order to oversee its functions.

More details on this matter are provided in Section 6.5.1.1.

6.2 Service provision

6.2.1 Types of services

A typical SBAS system would be expected to provide the following services, based on an international benchmark of SBAS programmes around the world:

- **The Safety of Life (SoL) Service** is specifically tailored to facilitate civil aviation operations, ensuring accuracy down to Localizer Performance with Vertical Guidance (LPV) minima. This service adheres to the International Civil Aviation Organization (ICAO) Standards and Recommended Practices (SARPs) for SBAS. Although initially oriented towards civil aviation, the SoL service has potential applications in various domains, including maritime, rail, road and unmanned aircraft.
- **Open Service (OS)**: The OS aims to enhance GPS positioning accuracy by correcting errors in GPS signals. It addresses issues related to satellite clocks, satellite position, and ionospheric effects. This service would be freely accessible in Africa for users with compatible receivers, without requiring specific certification. This service would be oriented to no safety-critical applications such as location-based services, geomatics or precision agriculture.
- **SBAS Data Access Service**: Tailored for users in search of elevated positioning performance for business and professional purposes. It allows authorized users, including application providers, to access real-time and historical FTP archives. Serving as the central hub for retrieving SBAS data generated by ground infrastructure across

Africa, SDAS facilitates connections to the Data Server. This enables application providers to deliver precise services using the SBAS products. Additionally, this service is useful for those applications where access to SBAS corrections through the Internet provides major added value in comparison with Signal in Space reception (i.e. urban canyons).

Other services potentially included could include:

- **PPP or PPP-RTK**: Tailored for users with demands for higher accuracy services. Precise Point Positioning (PPP) provides a global/regional precise positioning service by leveraging precise reference satellite orbit and clock products, in real-time using widespread networks of stations. The most important benefit of PPP with respect to classical differential approaches (e.g. RTK) is that it requires fewer reference stations to provide cm-level accuracy. On the other, the main drawback is the required convergence time (up to 10-20 minutes) to obtain a precise solution. To mitigate this limitation, the PPP-RTK concept introduces atmospheric corrections (together with the traditional PPP orbit and clock products) so that instantaneous ambiguity fixing is achievable, leading to shorter convergence times
- **Assisted Safety of Life for Maritime users:** This service was officially launched during the EGNOS workshop during March 2024.

Timing, emergency warning or search and rescue could be examples of other potential SBAS-related services, although a careful analysis should be performed to understand the potential of Galileo services in these areas.

While the SoL and Open services are expected to be free, if international examples are to be followed, other services designed for commercial or professional use could potentially involve associated fees for access.

6.2.2 Service Provision Scheme

This section describes in further detail the expected service provision scheme of the SBAS Safety-of-Life Service, as it is the most complex one in terms of relationships between stakeholders and liability. The figure below details the main relationships between the actors involved within an **Individual SBAS Programme**. *(The specific roles and responsibilities of the ownership, programme management and service provision layers have been detailed in the previous sections).*

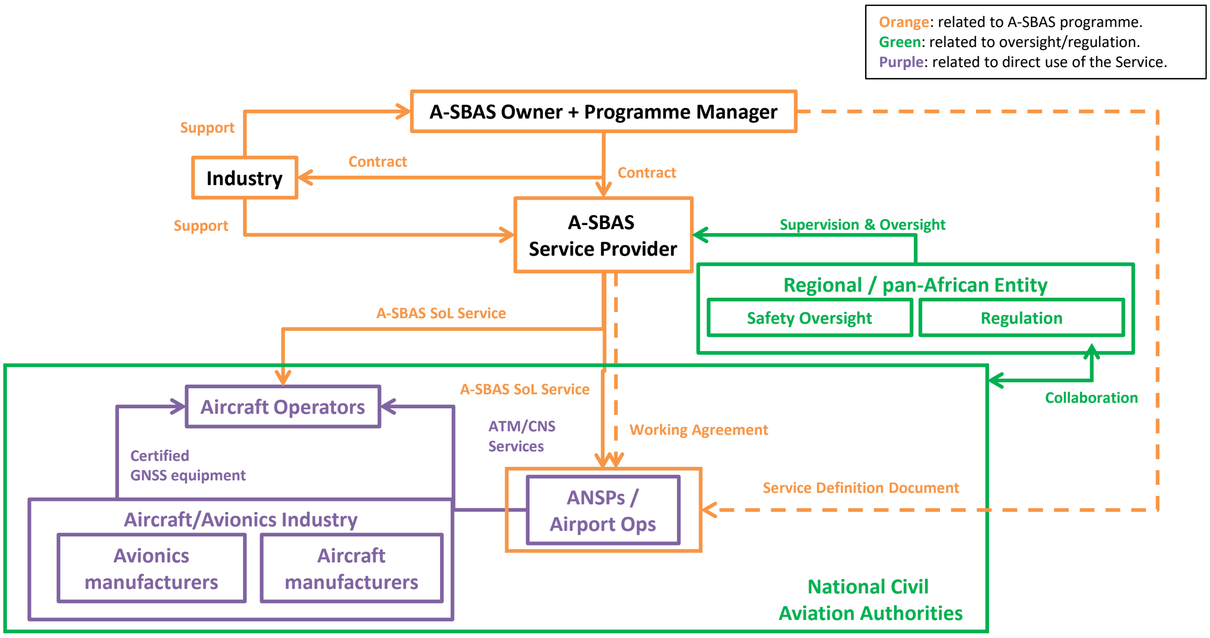


Figure 24: SBAS service provision scheme

The relationships between the different actors are typically expressed through two documents: The SDD and the Working Agreement

A **Service Definition Document (SDD)** must be published by the owner. The SDD describes the Service itself as well as the terms and conditions for accessing the service. It should include at least the following elements:

- Geographical service area in which the SBAS service will be made available for its use under certain conditions.
- Service description, describing its compliance with ICAO SARPs (Annex 10, Volume 1 – Radio Navigation Aids) requirements, including signal format, accuracy, integrity, availability and continuity.
- Terms and conditions to access the service (characteristics of SBAS receivers).
- Advises for sage use of the service.
- Cost of the service (if applicable).
- Description of liabilities.
- Points of contact for service provision.

The SBAS Owner + Programme Manager is liable for the **content of the SDD** and of the Service itself.

The **Working Agreement (WA)** is established between the SBAS Service Provider and the end users (ANSPs and airport operators), laying out the terms and conditions under which the SBAS service is provided to organisations implementing SBAS operations and laying out the working procedures and interfaces between the organisations. The WA must therefore always be aligned with the SDD.

Apart from the general content described in the SDD, the working agreement would ideally include the following elements:

- Management of service disruptions and anomalies
- Management of the maintenance works to the system ensuring that disruptions are minimized
- Notices to users
- Disposition of liability and insurance aspects
- Service performance monitoring
- Communications channels

The SBAS Service Provider is liable for **how** the service is provided according to what is described in the Working Agreement.

6.3 User engagement and service uptake

The primary objective of the user engagement initiatives is to foster awareness, understanding, and widespread adoption of SBAS across diverse user segments in Africa. This initiative aims to create a collaborative platform that brings together stakeholders from various industries to promote the benefits of SBAS technology.

The proposed activities are:

Raising Awareness

Implement a comprehensive awareness campaign targeting key industries such as aviation, maritime, agriculture, and land surveying. Utilize diverse communication channels, including workshops, webinars, and informational materials, to educate users on the benefits of SBAS in enhancing accuracy, reliability, and operational efficiency.

User Training Initiatives

Coordinate regional workshops and training programs tailored to the specific requirements of each industry. Offer hands-on training sessions to equip users with the knowledge needed for the seamless integration of SBAS into their existing systems and equipment.

Collaborative Demonstrations

Organize joint demonstrations of SBAS applications in collaboration with industry leaders and technology providers. Present tangible examples of how SBAS can improve navigation, precision agriculture, and other pertinent applications in real-world scenarios.

Industry-Focused Forums

Establish forums dedicated to specific industries where users can exchange experiences, discuss challenges, and share best practices related to SBAS implementation. These forums serve as networking platforms, fostering collaboration among stakeholders within each sector.

Incentive Initiatives

Investigate the feasibility of incentive programs or grants to motivate early adopters and showcase successful implementations. Acknowledge and reward organizations demonstrating effective utilization of SBAS technology.

Capacity building

Coordinate regional workshops and training programs tailored to the specific requirements of each industry

6.4 Economic viability

6.4.1 Cost Analysis

The SBAS deployment costs, calculated during Phase I, considered the scenario of a single system for the entire continent (continental model). This will now be expanded upon to show the estimated range of costs of the hybrid and complete regional solutions.

As a summary of Phase I, the following cost elements can be identified within an SBAS programme:

- **Infrastructure expenses**: Linked to the procurement, installation, operation and maintenance of all the ground infrastructure necessary to deploy an SBAS system, including RIMS, MCC, NLES and the data network (VSAT communications).
- **Space segment costs**: Cost of hosting an SBAS payload in a telecommunications satellite and leasing RF capacity (includes operations, telemetry and control and maintenance of the ground infrastructure…).
- **Programme development and management expenses**: This includes all the programme development costs that go beyond infrastructure (conceptual system design, studies to ensure technical feasibility of the system, system testbeds, organisational costs, market development costs, regulatory analysis, policy development…). This cost factor is greatly influenced by the level of reuse of the technology and the Technology Readiness Levels (TRL) of the system, as will be explained in greater detail in WP2- Technology Transfer Assessment.

  This category also includes any programme management expenses after entry into operations (programme evolutions, user uptake activities…).
- **SBAS service provision costs**: Costs related to the wages of the personnel in charge of service provision and system operation.

The full methodology employed, and the assumptions taken for the cost exercise are included in Task 1 of Phase I of the CBA.

The cost comparison between the continental, regional and hybrid solutions is presented in terms of capital expenses and operational expenses.

In the case of capital costs, there is an increase in infrastructure expenses for the case of regional and hybrid configurations. The increase is mainly due to the fact that certain elements of the infrastructure (namely the MCC and the NLES) must be duplicated for each system. However, the difference is mitigated by the fact that certain elements (RIMS) are independent of the number of SBAS systems in the continent, as they have a proportional relationship with the size of the area to be covered.

In terms of programme development, a regional model would imply double the costs of the continental scenario, as there are no shared functions or development activities. For the hybrid configuration, it is assumed that certain elements (market development activities, regulatory and policy-making processes) and certain technological transfers will be shared between the different systems, deriving in a certain cost reduction over the regional solution

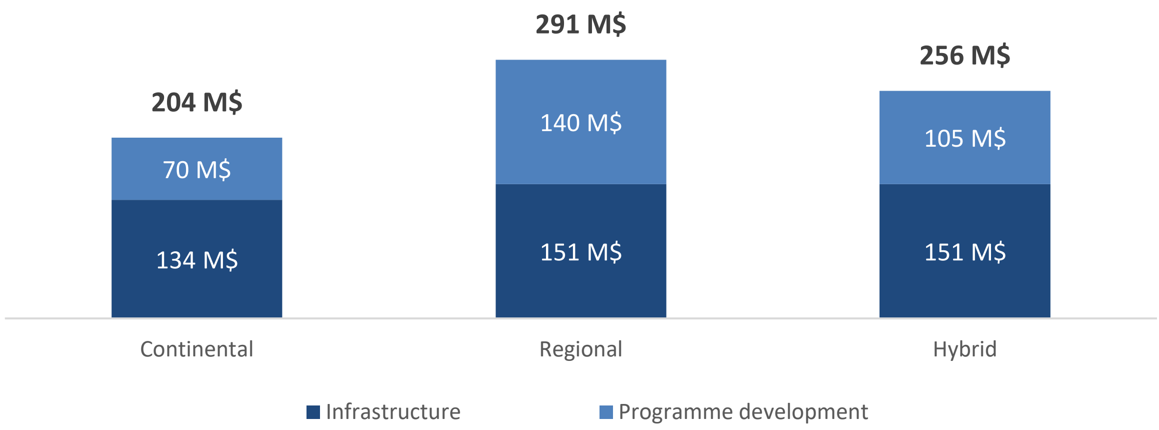


Figure 25: SBAS centralisation scenarios capital cost comparison (M$)

In terms of operational costs, a regional system implies almost doubling the yearly expenses, as there are no common elements in terms of programme development, space segment costs or service provision, as well as slightly higher infrastructure operational expenses due to certain element duplications (NLES and MCCs).

A hybrid solution, albeit more costly than the continental model, implies significant cost reductions over the regional configuration. First, recurrent programme management costs are assumed to be the same due to the shared common entities (policies, programme roadmap, market development…). Additionally, with the help of the common African SatNAV Programme Oversight, other arrangements could be put in place to explore cost efficiencies (common personnel for system maintenance, sharing the same backup satellite…).

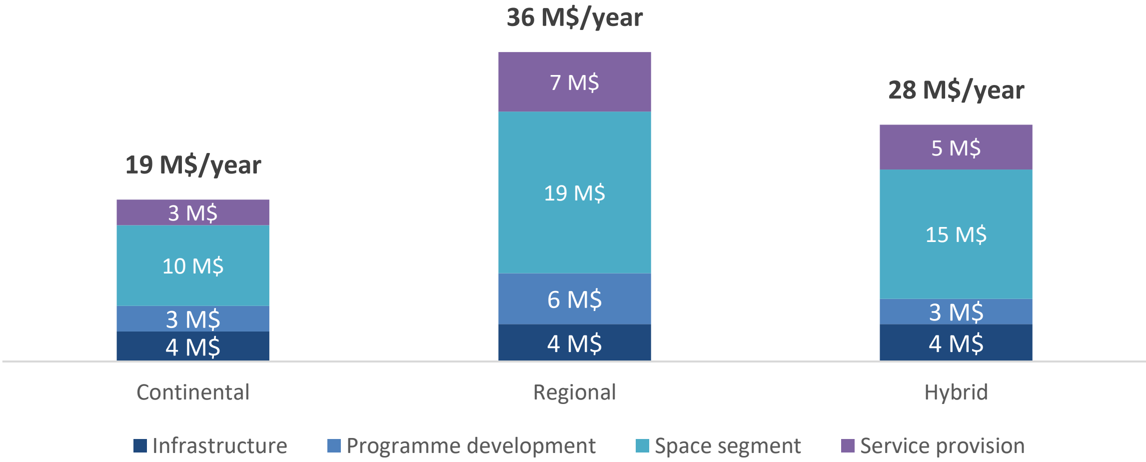


Figure 26: SBAS centralisation scenarios operational cost comparison (M$/year)

Several key outcomes are derived from this analysis:

- An SBAS Programme is cost-intensive and will require **significant funding** to face both upfront investment and operational expenses.
- It is evident that opting for **more decentralised solutions implies greater programme costs**. However, this fact has already been considered and evaluated in the multicriteria analysis as the main benefit of the continental solution. Nevertheless, **the benefits provided by the Hybrid Model in all other criteria** (operational, regulatory, organisational…) **outweigh this element.**
- Considering **EGNOS v3** coverage expansion plans due to DFMC technology, it will be possible to cover Northern Africa for free, without the need for any investments by African entities, **significantly reducing the financial burden of African stakeholders in the Hybrid model**, as these costs will be covered by the European Commission.
- Due to the cost overhead of the hybrid solution, it is **recommended to ultimately have two to three SBAS programmes at most in Africa** to increase the financial sustainability of the overall programme.

6.4.2 Funding mechanisms

The values provided above evidence that the African SBAS requires considerable investment. As the institutionalisation model proposed in Section 7.1, has two main layers: Political-level and Programme-level, two levels of funding are proposed:

<u>Funding for the African SatNAV Programme – Political oversight layer</u>

The African SatNAV Programme is proposed to be formed under the umbrella of the African Space Agency. This means that the **funding from all activities proposed in this layer** (policy making, services roadmap development, regulatory harmonization, market development activities…) **would be expected to be obtained from AfSA, and therefore, from the African Union**, which would receive the contributions from its Member States.

Funding for the individual SBAS Programmes

The institutional model proposed leaves certain independence on how the individual SBAS Programmes will carry out their programme. It is therefore proposed that **the financial burden of each individual programme should be carried by the respective SBAS Owner + Programme Manager.**

No specific recommendation is made on how this funding could be received. Below is a list of potential options and mechanisms that could be explored to help achieve the necessary funding level:

This funding could come from a combination of various sources:

- **Cost transferred by States / RECs**: This option involves the cost transfer from African States or Regional Economic Communities (RECs). These states could either contribute directly or through specific institutions of the States, which would be linked to the "champions" of the SBAS initiative (namely ANSPs at the moment). In this regard, a cost-apportioning exercise could be performed, distributing the capital and operational expenses of the programmes depending on the expected impact on the stakeholders of the different target markets (aviation, maritime, agriculture, rail…).

  A preliminary exercise was performed in Task 3 of the SBAS CBA, in which capital costs were apportioned between aviation, maritime, and agriculture stakeholders, although more industries could be included in this framework. A grant was also modelled in this analysis, although its value is considered an estimation based on past grants given to transport development projects and could vary.

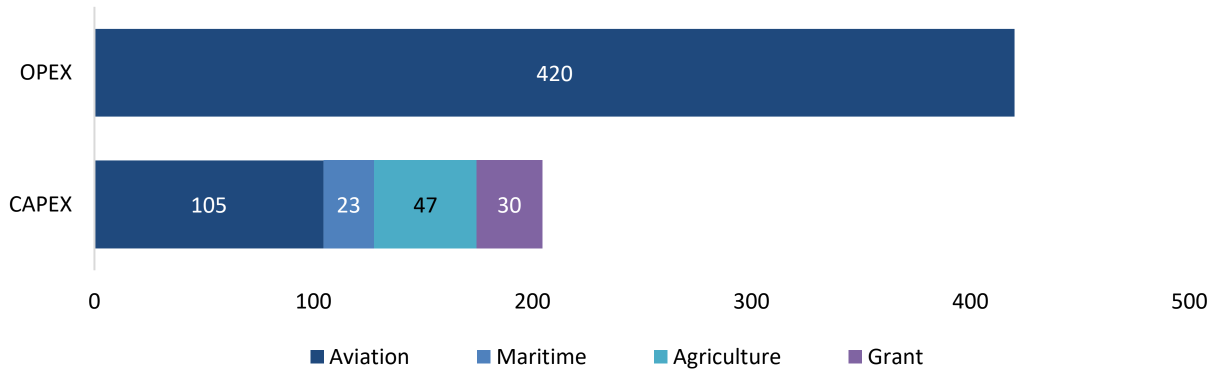


Figure 27: SBAS implementation cost apportioning scenario (in M$)

- **Multilateral funding**: Funding could be obtained from multilateral agencies, such as the African Development Bank, the African Export and Import Bank, the World Bank or the International Finance Corporation.

- **Grants**: There is extensive evidence of external aid in the form of funds and grants to African stakeholders, destined for development projects, including transport and infrastructure. Additionally, this willingness to cooperate with external institutions is reflected in the latest EU-ASECNA Cooperation Agreement on the development of satellite navigation (Decisions EU 2016/2234 and EU 2018/1603).

  However, grants will have a limited impact as these are usually limited in size and sometimes restricted to a period of time/usage/tied to other rules

As an alternative, PPPs could mobilise additional financial resources from the private sector, alleviating the public burden of providing the full capital outlay for SBAS infrastructure, although this model presents several short-term drawbacks, as presented in Section 7.

6.4.3 Revenue generation

In the continental workshop held in Kigali in May 2022, the African airspace users (AFRAA and IATA) supported the implementation of SBAS in Africa provided certain requirements, one of them being that **no costs or charges related to SBAS being imposed directly or indirectly to airspace users who do not use such technology.** SBAS Safety of Life Service is expected to be free, both in aviation in potentially in other transport sectors such as maritime. SBAS Open Service is also expected to be free if the European example is followed**.**

Possible funding could come from the exploitation of SDAS and other auxiliary services (PPP/ PPP-RTK) and could act as a supporting mechanism for SBAS funding. However, this is not expected to occur in the first programme stages, meaning that funding would have to be supported by public sources.

6.5 Regulatory framework

6.5.1 Aviation

6.5.1.1 Certification

In the Safety-of-Life (SoL) service, SBAS user equipment must adhere to specific standards for certification. For example, civil aviation SBAS equipment must demonstrate full compliance with:

- RTCA SBAS MOPS DO-229 (airborne equipment)
- RTCA SBAS MOPS 228 and 301 (antenna requirements)
- ED-259 MOPS for Galileo – GPS- SBAS Airborne Equipment
- ED-134 Signal Specification for SBAS L1/L5
- ED-157 SBAS L1/L5 ICD
- ETSO-C145e – Airborne Navigation Sensors using GPS augmented by SBAS

- ETSO-C146e – Stand-alone airborne Navigation Sensors Using the Global Positioning System (GPS) Augmented by the Satellite-Based Augmentation System (SBAS)

Additionally, at installation level, these systems must demonstrate compatibility with other avionics equipment, particularly Flight Management Systems (FMS), which may imply different levels of retrofitting depending on the case.

Certified SoL civil aviation equipment is positioned as a high-cost solution, with numerous manufacturers worldwide, such as Thales, Honeywell, Collins Aerospace, General Avionics, etc.

The Open Service (OS) is geared towards cost-effective, general-purpose GNSS equipment using the SBAS system to enhance accuracy performance compared to standalone GNSS devices. Unlike the certification requirements for SoL user equipment, OS user equipment may not necessarily comply with RTCA MOPS DO 229 processing rules but may only utilize processing algorithms that incorporate accuracy corrections from the SBAS.

The SBAS service provider must be certified. In Europe, the EGNOS certification requirements baseline must guarantee the Single European Sky Regulatory Package.

In Africa, the Single African Air Transport Market (SAATM) is a flagship project of the African Union Agenda 2063, an initiative of the African Union to create a single unified air transport market in Africa to advance the liberalization of civil aviation in Africa and act as an impetus to the continent's economic integration agenda. The SAATM was created to expedite the full implementation of the Yamoussoukro Decision.

Regional Monitoring Centres (RMCs) play a crucial role in the governance and operational framework of SBAS in Africa. Their establishment would be a cornerstone for ensuring the system's reliability and trustworthiness, tailored to the specific needs and conditions of different African regions. The operations shall be proposed as follows.

RMCs could host training and certification programs for SBAS technicians and analysts, contributing to capacity building within the region. By fostering knowledge sharing among the different RMCs across Africa, these centres would ensure that best practices are disseminated and adopted uniformly.

Similar to Europe, in order to certify an entity as an SBAS Service Provider, compliance with the regulatory framework of the SAATM (Single African Air Transport Market) would be required, among other Standards provided by the ICAO Annexes. **Individual national Civil Aviation Authorities or a Level 3 RSOO would be responsible for granting such certification; or alternatively, a Civil Aviation Authority (CAA) may delegate this function to a competent RSOO.** Article 28 of the Chicago Convention allows for the delegation of a State's functions and duties to either another State, International Organisation or non-governmental entity. However, it should be noted that this does not release the delegating State of its oversight responsibilities. This action shall be made legal with an agreement between the Parties. The

CAAs that delegate the certification function must ensure that they perform oversight of this delegation.

6.5.1.2 Service Liability

The issues of liability and compensation in the context of SBAS systems are complex and are often governed by a combination of international treaties, national laws, and contractual agreements. Understanding the liability framework is crucial for all parties involved in the operation and use of SBAS services.

Liability for defective service is an incentive for maintaining a high standard of reliability for GNSS. Liability of the SBAS providers for defective control and navigation would compensate users for damages experienced from defective service. The ICAO Assembly Resolution 32-19 cautioned GNSS providers to ensure the reliability of their GNSS services, "including effective arrangements to minimise the operational impact of system malfunctions or failure, and to achieve expeditious service recovery."'

International Liability Framework

Convention on International Liability for Damage Caused by Space Objects (1972)

This Convention outlines the principles for liability for damage caused by space objects, including satellites used in GNSS systems. In this context, the types of liability include:

- Absolute Liability: States that launch space objects are liable for damage caused on the surface of the Earth or to aircraft in flight.
- Fault-Based Liability: For damage caused elsewhere than on the surface of the Earth (e.g., in outer space), the liability is based on fault.

Registration Convention (1975)

This requires States to furnish details about the orbit of space objects, which is crucial for liability determinations if an incident occurs involving space debris or malfunctioning satellites.

National Legislation on Liability

Country-Specific Laws

Countries that operate or use GNSS-SBAS systems should typically have their own legal framework detailing the responsibilities and liabilities of operators and service providers. These laws usually outline the conditions under which operators can be held liable and the processes for seeking compensation.

Contractual Liability

SBAS service providers and users often enter into SLAs that define performance standards, liability limits, and compensation mechanisms. These agreements can limit the liability of the service provider under certain conditions and outline the process for claiming damages.

Further, satellite operators are often required by national law or international agreements to hold insurance that covers potential liability risks. The insurance should be adequate to compensate for the damages in the event of a malfunction or accident resulting in harm.

Dispute Resolution Mechanisms

International Arbitration and Courts

In case of disputes, parties may resort to international arbitration or submit their claims to international courts or tribunals. There are also specialised bodies, such as the International Court of Justice (ICJ), which may have jurisdiction over certain types of disputes involving space activities.

In this instance, the newly established Dispute Settlement Mechanism under the auspices of the AFCAC may adequately address the issues related to SBAS implementation in Africa. Further, the East African Court of Justice, which also doubles as an arbitration tribunal may be considered to address matters that arise within the jurisdiction of the East African Community.

User Liability

Users of SBAS services may also bear liability if they fail to use the services appropriately or if they cause interference or damage to the system. National laws may outline the penalties or compensation requirements for users who misuse or interfere with SBAS services.

In summary, the liability and compensation mechanisms for SBAS systems involve a multi-layered legal structure that integrates international treaties, national laws, and contractual agreements. This structure is designed to ensure that there are clear processes for addressing damages or losses arising from the operation or use of SBAS services, with the aim of maintaining the trust and reliability necessary for the continued growth and development of these critical systems.

Enforcement And Dispute Resolution

The legal framework for GNSS-SBAS systems must incorporate mechanisms for enforcement and the resolution of disputes. This involves both international and national instruments and bodies that can interpret and apply the legal norms governing space activities, including the operation and use of SBAS. The enforcement and dispute resolution processes are vital for maintaining the rule of law in space activities and ensuring that the rights and obligations of states and private entities are upheld.

The International Civil Aviation Organization (ICAO) plays a role in the enforcement of standards and practices for international aviation, including those that apply to GNSS-SBAS. While ICAO does not have direct enforcement power, it influences through its standards and recommended practices (SARPs) and audits of member states.

The ITU is responsible for regulating the use of the radio-frequency spectrum and satellite orbits, including those used by SBAS. It has mechanisms to resolve frequency interference disputes, which can be critical for SBAS operations.

Important to note is that through its dispute settlement system, the WTO may address disputes related to trade aspects of GNSS-SBAS services, especially where such services are part of broader trade agreements.

National Enforcement Bodies

National regulatory bodies are typically responsible for enforcing satellite licensing requirements, allocation of frequency spectrum, and adherence to SBAS operational standards within their jurisdictions; while domestic legal disputes concerning SBAS services, such as contractual breaches or liability claims, are usually addressed by national courts.

Dispute Resolution Mechanisms

Parties to a GNSS-SBAS agreement may choose arbitration as a means to resolve disputes. Arbitral institutions such as the International Chamber of Commerce (ICC) or the London Court of International Arbitration (LCIA) provide forums for such arbitration. States may further engage in diplomatic negotiations to resolve disputes concerning SBAS services, particularly those that involve state actors or cross-border issues. International courts, such as the International Court of Justice (ICJ), may have jurisdiction over disputes between states related to space activities, including those involving SBAS systems.

Compliance Monitoring

Entities like the ITU and ICAO monitor compliance with international regulations. For SBAS, monitoring centres may also track performance and adherence to standards.

Sanctions and Remedies

International and national bodies can impose sanctions for non-compliance with SBAS regulations, such as fines, withdrawal of licenses, or restrictions on operations; while legal frameworks must provide remedies for those harmed by non-compliant activities, such as compensation for damages or injunctive relief to prevent further harm.

Legal Awareness and Capacity Building

To ensure effective enforcement and dispute resolution, stakeholders need training in the applicable legal regimes and procedures. The provision of legal advisory services can help states and private entities navigate the complex legal landscape of SBAS.

In conclusion, the enforcement and dispute resolution mechanisms for SBAS in Africa must be robust and clearly defined to ensure that all parties act in compliance with their legal obligations and that there are effective means to resolve disputes. This aspect of the legal framework is essential for fostering an environment of trust and reliability, critical for the successful operation and widespread adoption of SBAS services.

Legal Challenges in Compensation

In the event of a failure within an SBAS for any reason, the current legal frameworks and scholarly research provide limited assurances for ensuring that victims receive just, timely, and appropriate compensation. This is due to several factors:

a. There is a lack of specific international regulations or comprehensive proposals tailored for GNSS-SBAS systems. Additionally, there is no defined method for the application of either existing international conventions or national laws by legal experts, which is further complicated by jurisdictional conflicts arising from the global scope of SBAS systems.

b. The concept of national sovereignty significantly hampers the practical application of civil liability theories concerning GNSS. This concept is firmly rooted in the legal system, as evidenced by Article 1 of the Chicago Convention and Article 3(b) of the ICAO Charter on the Rights and Obligations of States pertaining to GNSS Services.

c. Although most national laws strictly prohibit the use of jamming and spoofing devices, these are still readily obtainable online, indicating a disregard for legal provisions aimed at preventing interference with GNSS and SBAS signals.

d. It is often not straightforward for the general public to discern liability for damage resulting from the use of GNSS services or signals as opposed to GNSS-enhanced or supported services. Furthermore, proving and identifying the distinction can be exceedingly challenging for those affected without specialised knowledge. This situation sometimes forces GNSS service providers to assume the responsibility of educating the public about legal issues related to civil liability.

e. It is critical to differentiate between the various entities involved in the SBAS supply chain when considering civil liability issues within SBAS. As dependence on SBAS increases, these highlighted concerns represent real, latent threats of damage resulting from SBAS utilisation. To avert potential crises, it is advisable to adopt measures from technical, financial, institutional, and legal standpoints.

6.5.2 Other non-aviation sectors

To effectively implement Satellite-Based Augmentation System (SBAS) technologies across non-aviation sectors e.g., maritime, rail, road, and agriculture—a nuanced approach to oversight and governance is essential. This involves the establishment or enhancement of sector-specific regulatory bodies and frameworks, which may necessitate evolving existing guidelines, such as those by the International Maritime Organization (IMO) for maritime navigation and safety; or creating new standards within international railway standards organisations like the International Union of Railways (UIC) for rail safety and signalling.

In the road sector, collaboration with national road safety authorities and international entities like the World Road Association (PIARC) would be critical to integrate SBAS into traffic management systems effectively. Similarly, in agriculture, partnerships with agricultural departments and global organizations are vital to promote precision farming through SBAS.

The development of technical standards and certification processes may be looked into to ensure the reliability and safety of SBAS applications. This step involves crafting minimum performance standards for SBAS-enabled equipment and systems and establishing certification processes for equipment manufacturers and service providers, aiming for a high level of interoperability among diverse systems.

Oversight mechanisms are crucial for ensuring adherence to these standards and regulations. This could be achieved through the setup of interagency committees or working groups that span across different sectors, conducting regular audits, and maintaining a robust incident reporting and investigation framework to swiftly address any SBAS-related issues.

While specific legal frameworks or documentation directly supporting these suggestions may vary by region and sector, the principles are broadly supported by existing international agreements and standards related to global navigation satellite systems (GNSS). Documents such as the ICAO Standards and Recommended Practices (SARPs) for aviation, which could be adapted or serve as a model for other sectors, and the United Nations International Committee on Global Navigation Satellite Systems (ICG) recommendations, offer guidance on the use of GNSS, including SBAS, across various applications.

In principle, the implementation of African SBAS in non-aviation sectors would still in principle require an aligned oversight mechanism, using the already existing frameworks in place, customised to fit within the scope of the different sectors, with reference made to the respective national and international bodies governing these sectors. However, instead of RSOOs being involved in aspects of regulatory harmonisation, and due to their limited mandate in aviation and the distinct nature of the non-aviation sectors, the RECs could ably take on this role depending on the agreed areas of cooperation- which usually include these sectors.

7. Implementation roadmap

A high-level overview of the key tasks to be performed over the next ten years is provided below:

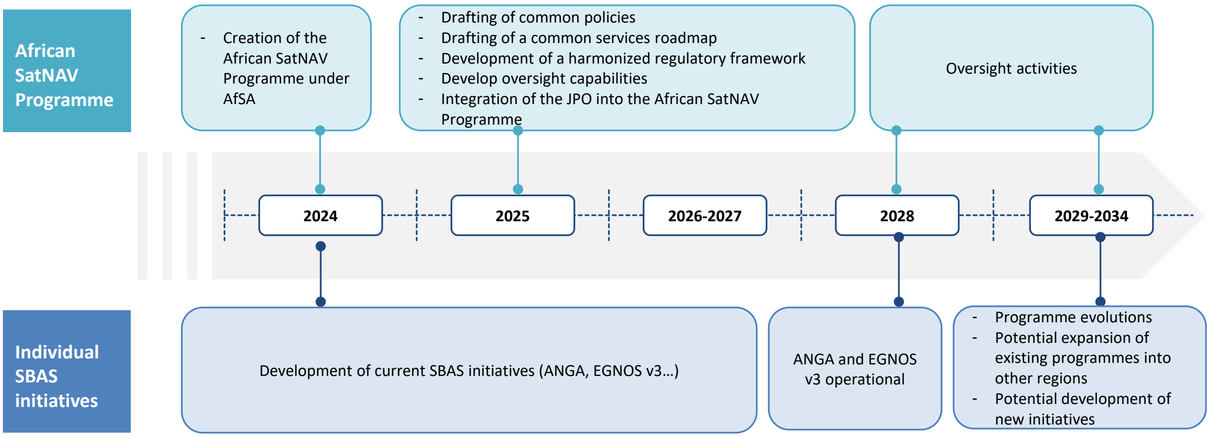


Figure 28: Ten-year roadmap

The roadmap is divided into two main sections, one focused on the political layers (African SatNAV Programme) and the other more related to the individual SBAS initiatives.

African SatNAV Programme

After the Validation and Continental Workshop that will take place within the Continental SBAS CBA project, this institutionalisation proposal is to be presented to the AU Policy Organs, for its approval. This would mark the trigger and lead towards the creation of the **African SatNAV Programme,** coordinated under AfSA, before the end of 2024, to coordinate all continental activities related to SBAS.

Once the Programme is created, from 2025 onwards the main tasks would involve:

- Drafting the common SBAS Policy and common services roadmap.
- Working with AFCAC and the RSOOs on a harmonized regulatory and certification framework.
- Setting up the role of SatNAV Africa JPO as the market development agent of the African SatNAV Programme.

After the SBAS programme(s) in Africa becomes operational, the African SatNAV Programme would exercise its oversight role.

Individual SBAS initiatives

From 2024 to 2028, the two currently ongoing SBAS initiatives that will provide services to the continent (ANGA and EGNOS v3) are expected to continue their development according to their internal roadmap. As presented in the Third Meeting of the Steering Committee of the Action III of SatNAV Africa JPO, both initiatives have plans to become operational by 2028, covering most of Northern and Western Africa as well as Madagascar.

After initial entry into operations, these programmes could evolve, potentially adding new services to their portfolio. From that point, two possibilities appear to provide SBAS services to the entire African continent:

- ANGA and EGNOS v3 could potentially expand their service areas into other regions until full continental coverage is provided. This could happen either by expanding their network of infrastructure by deploying RIMs in other regions and entering into SLAs with the national ANSPs, or organically through DFMC technology (which automatically increases the coverage area for the same ground infrastructure)
- Other initiatives could potentially appear in certain regions (East, South), which could develop under the oversight of the African SatNAV Programme

8. Coherence with African Space Strategy

The use of space applications to facilitate responses to Africa's most pressing socio-economic challenges are grouped into four key thematic areas: Earth Observation, Navigation and Positioning, Satellite Communications and Space Science and Astronomy

Within Navigation and Positioning, several interventions are included. A traceability of the contribution of African SBAS to the interventions is outlined below:

AfSA Intervention area	Contribution of SBAS to African SatNAV Programme
Developing adequate skills and expertise in navigation and positioning applications and usage.	**YES** The proposed solution implies increasing African indigenous capabilities in the SBAS system design, procurement, installation, testing, operation and maintenance, as will be detailed in WP2 – Technology Transfer and Risk Assessment
Ensuring seamless integration into existing global navigation satellite services.	**YES** The regulation oversighting body will ensure seamless integration with other SBAS systems in adjoining airspace
Building on existing infrastructure such as the Agency for Aerial Navigation Safety in Africa and Madagascar, TRIGNET (a network of continuously operating global navigation satellite system base stations) and the African Geodetic Reference Frame.	**YES** The proposed solution leverages existing SBAS programmes, such as ANGA, led by ASECNA
Developing an indigenous continental-level navigation augmentation system.	**YES** More details to be found in as will be detailed in WP1.2 – Technology Transfer and Risk Assessment

AfSA Intervention area	Contribution of SBAS to African SatNAV Programme
Developing navigation and positioning application products and value-added services to support user requirements.	**YES** The proposed SBAS service in Africa is expected to have a Safety of Life, Data Access and Open Service (the latter available for all users in all sectors) Additionally, the market development functions led by SatNAV Africa JPO are expected to promote navigation products and added-value services.
Promoting an African array study for seismic applications using seismic reference receivers.	**NO** No impact is expected in this area.

Table 16: Contribution of African SBAS towards African Space Strategy

Work Package 2: Technology Transfer and Risk Assessment

9. SBAS Technology Transfer Assessment

The objective behind this analysis is to define the level of technological involvement that Africans stakeholders should have in the SBAS system development in the continent.

9.1 SBAS system development options

There are three main options regarding SBAS system development for African SBAS

- **Full independent system development**: This implies African stakeholders developing a full SBAS system without making use of the knowhow acquired in other geographies, developing all aspects of the SBAS value chain from design to testing and operations

  In a general sense, this option entails the highest upside for the continent, as it would imply the acquisition of the full range of capabilities necessary to develop and operate and SBAS system. However, it also entails the highest level of technical and economic risk as there is a higher probability of failure given the complexity of the venture and the lower level of maturity of African aerospace industry.

- **Development through technology transfer:** This implies African stakeholders developing an SBAS system based on existing and proven technology in other operational SBAS systems. Certain aspects of the SBAS value chain would be developed independently or collaboratively, while other parts of the SBAS system may be externalized

  In a general sense, this option has high upside for the continent, as it also allows to develop indigenous capabilities, exploiting and developing African talent for certain activities in the program's development (the extent of these activities is detailed in later sections of the report), while also leveraging on success stories and the expertise of international partners.

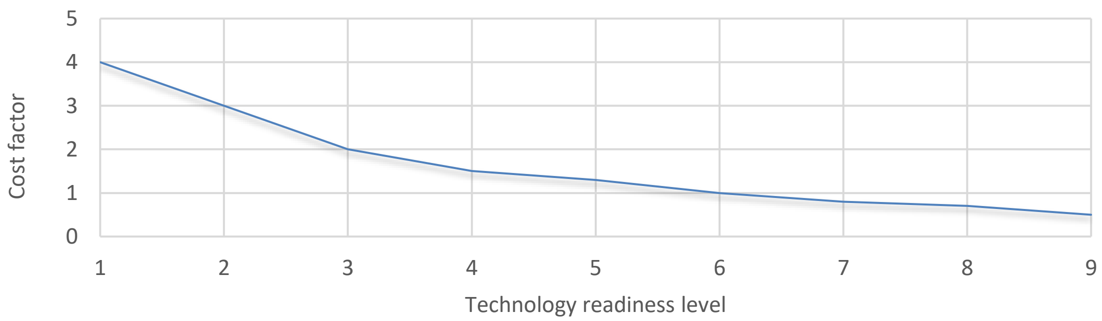


Figure 29: Technology Readiness Level and cost reduction relationship: Source – The New SMAD

As illustrated in Figure 29 there is a clear cost reduction in aerospace projects as technology is consolidated with a cost decrease of a factor of 3 to 4 on average when moving from low TRLs (1-3: formulation of technological concepts, proof of concepts…) to high TRLs (7-9: system proven in operational environment)

The key factor in the technological transfer is **which elements to develop independently or in collaboration, and which to import directly,** for which a deeper understanding of the system and the development value chain is necessary.

- **Full technology import from third party:** This implies delegating the responsibility of SBAS system development to a third party, with very limited involvement of African stakeholders

  This option presents the lowest level of risk in terms of technical development of the system, as it relies on experienced technology providers. There is however a level of risk in terms of the complete dependency towards the third party, how is in control of the entire development and system commissioning process. The main drawback however is the lack of acquired know-how for African stakeholders, which will gain no capabilities from the development of the SBAS system.

An international benchmark of the different development models for certain operational and planned SBAS systems has been performed and is represented in Figure 30.

SBAS Programme	Development type		Development owner	Key Contractor (s)
WAAS	1	Independent system development	Federal Aviation Administration	Raytheon Technologies
EGNOS	1	Independent system development	esa European Space Agency	ThalesAlenia Space; AIRBUS DEFENCE & SPACE
	1	Independent system development	JCAB	NEC
KASS	2	Development through technology transfer	KAIA Korea Agency for Infrastructure Technology Advancement	ThalesAlenia Space; ETRI; KARI
SouthPAN	3	Full technology import from third party	Full development responsibility delegated to contractors	LOCKHEED MARTIN; gmv

Figure 30: SBAS development options international benchmark

Note: Non-exhaustive. Not all SBAS Programmes are included in the Figure

As we can see, WAAS, EGNOS and MSAS were developed independently with a local design agent and domestic companies as the prime contractors. KASS is an example of development through technology transfer, as KAIA (Korean Agency for Infrastructure and Technology Advancements) acting as a design agent, with the participation of both local institutions (KARI, ETRI) and international contractors (Thales Alenia Space) in the system development. Finally, Australia and New Zealand selected Lockheed Martin and GMV as main contractors in the Southpan programme, delegating almost all functions with little involvement in the technical development of the programme.

A deeper dive is performed at the Korean KASS Programme, based on technology transfer. KASS' development model is presented in Figure 31 below:

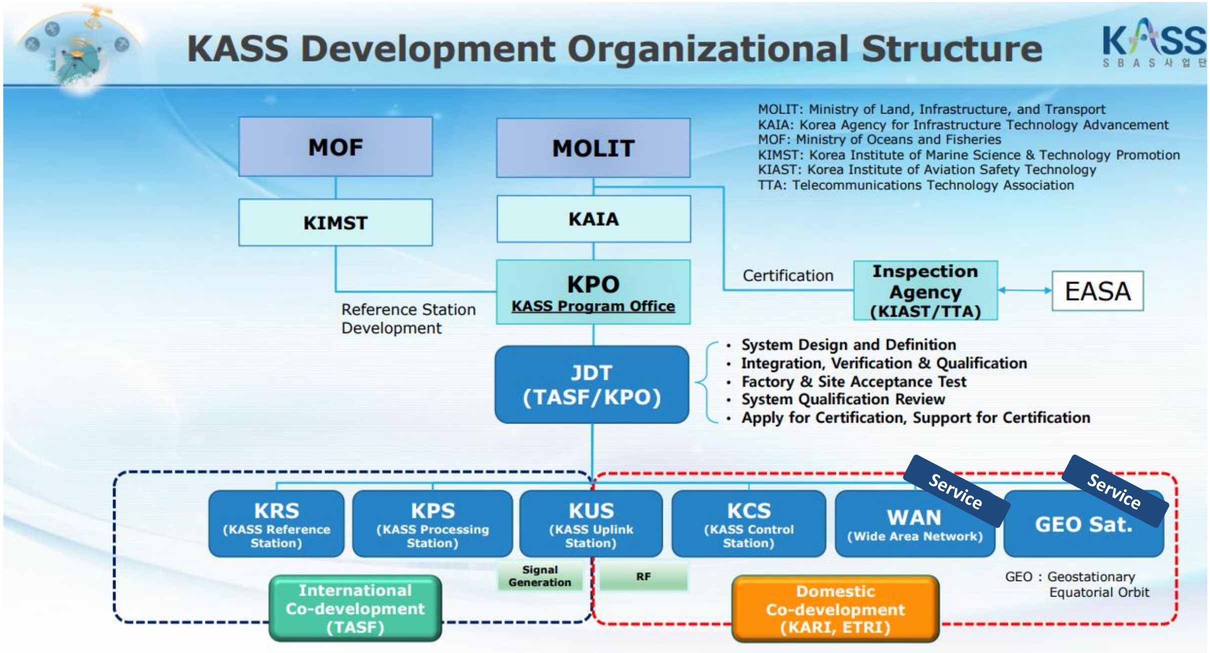


Figure 31: KASS development model – Source: KASS

The main principle was the creation of a Joint Development Team (JDF), formed by TASF (Thales Alenia Space – France) and KPO (KASS Programme Office) which **oversaw system design, definition, integration, verification, testing, qualification review, and certification.** This KASS was formed by national actors, the Korean Agency for Infrastructure Technology Advancement and the Korean Institute of Marine Science and Technology Promotion. The bottom part of the image illustrates how the different components of the SBAS system were developed

- **Thales Alenia Space – France (TAS-F):** Most subsystems (RIMs, Processing Centre and most of the subsystems in the Uplink stations) were designed, developed and integrated by TAS-F, with the technology based on the EGNOS system. **This includes the engineering, performance, integration, verification of these systems.** TASF' scope of services also included overall **system integration** of its systems and those developed in the Korean environment (to be detailed next bullet)
- **KARI** (Korean Aerospace Research Institute), **ETRI** (Electronics and Telecommunications Research Institute): In charge of the development of the KASS Control Station (KCS), certain elements of the KASS Uplink Station (interface with the

geo satellite) and the geo satellite.
(It must be mentioned that the development of the Geo satellite had dual purposes, telecommunications and the KASS programme, justifying its internal development. For the KASS programme, this satellite can be considered a service.)

Overall, the core engineering and design responsibilities resided in the international partner, **TASF, who oversaw the most critical elements of the system as well as its integration**, (The KCS, developed by KARI is key to system operation but does not contribute to the system's performance levels). Nevertheless, the KASS Programme can be considered a success story of technology transfer, in which the domestic actors took a role in the development of the system.

The objective is to find the appropriate technological partnership model for Africa, examining the synergies created with international partners in terms of technological transfer and identifying the areas in which to promote the "Indigenous" SBAS capabilities

9.2 High-level SBAS architecture and subsystems Identification

Before deciding on the appropriate SBAS development model, a high-level understanding of the SBAS architecture and main systems is necessary. An SBAS system comprises various subsystems that need to operate cohesively to enhance the GNSS signal and provide the required services to users.

The subsystems are identified in Figure 32 and can be classified according to these two main categories:

- **Infrastructure**: Includes all the systems necessary for the operationalization of SBAS including Space infrastructure, Airborne equipment, Data network, and SBAS ground equipment
- **Service Provision:** Includes all aspects related to delivering the service to SBAS users.

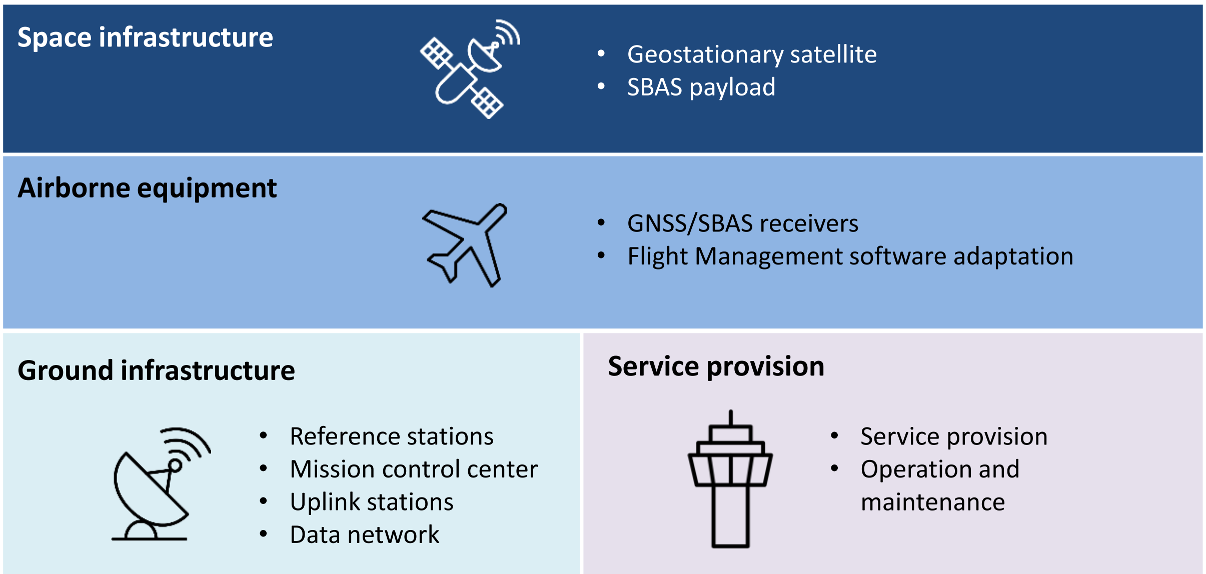


Figure 32: SBAS subsystems identification

9.3 Technology Transfer Assessment

A technical analysis will be conducted for each of the subsystems to determine the potential for either complete indigenous development within Africa, a technology transfer or a complete technological import. The ultimate solution may adopt a hybrid approach, given that each subsystem will be analysed independently.

The high-level process followed is presented in Figure 33, albeit with certain differences to account for the particularities of the different subsystems:

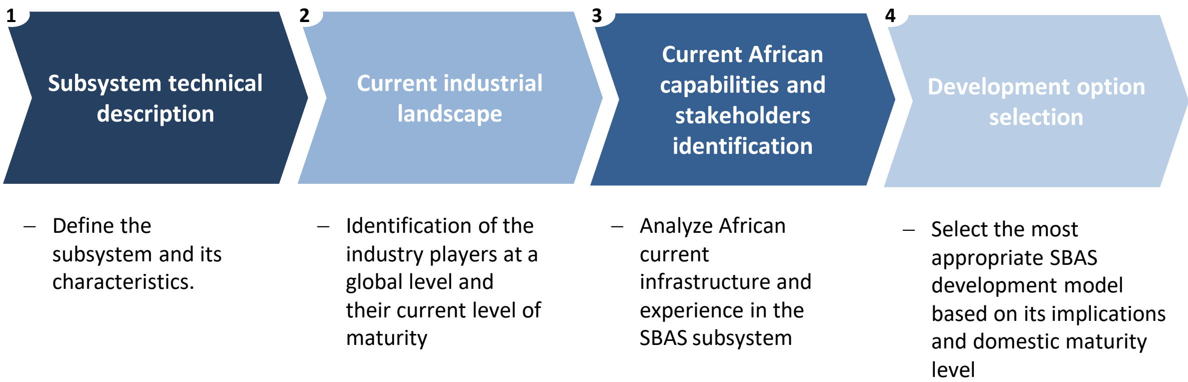


Figure 33: Technology Transfer Assessment Methodology

It must be noted that certain SBAS system layers, namely the ground segment, will be tackled in more detail, due to their greater technological transfer implications

9.3.1 Space Infrastructure

Subsystem technical description

A typical SBAS Space segment comprises of two geostationary satellites (GEO) with navigation payloads in charge of transmitting a GNSS-like carrier signal with the SBAS information. Typically, the SBAS satellites are multi-purpose, commercial communication satellites that carry out an additional SBAS navigation payload.

Current industrial landscape

As an example, the EGNOS network does not possess its own Space Segment; instead, it has hosted SBAS payloads in commercial geostationary communications satellites Astra SES-5, Astra-5B and Inmarsat 4F2 EMEA. For the case of GAGAN, it uses three dual purpose GEO satellites, GSAT-8, GSAT-10 and GSAT-15, all built by the Indian Space Research Organisation with the primary objective of satellite communications in the Indian subcontinent, and with the GAGAN payload as a complementary mission. This trend of hosting a payload in a commercial GEO-satellite is widespread across all programmes (KASS, MSAS, WAAS…)

Current capabilities in Africa

In Africa, there are some satellite operators and service providers, such as NIGCOMSAT, a Nigerian government-owned agency. This company, for instance, has experience in operating communication satellites and providing satellite-based services, including telecommunications, broadband, and broadcasting in Nigeria and the surrounding regions. NIGCOMSAT has already been used for ANGA's trials and field demonstrations, broadcasting SBAS signal since September 2020. Other countries that have developed and operate geo telecommunications satellites are Algeria (Alcomsat-1), Egypt (Nilesat 201 and 301), Angola (Angosat-2) and South Africa

Additionally, we find three GEO telecom satellites that have been launched as multilateral projects, two of them launched under an agreement with RASCOM (Regional African Satellite Communication Organisation), representing 44 telecommunication operators as well as NewDawn, built for Intelsat and Convergence Partners.

Regarding satellite development capabilities, Nigeria, South Africa and Egypt are all developing infrastructure for assembly, integration and testing of satellites, while other countries are developing experimental CubeSat projects. However, all these initiatives are mostly focused on smaller Earth Observation satellites, as no Africa country or company has yet developed the capabilities to build telecommunications GEO satellites.

Alternatively, due to the orbits and geostationary satellites, and the similar geographical longitude of the European and African continents, the African SBAS payload could also be hosted in a European telecommunications satellite. Several companies could be appropriate in this regard, including Eutelsat, which operates a fleet of geostationary satellites that can provide coverage over large areas, potentially making them well-suited for SBAS applications in the continent. Other commercial operators (Intelsat, Amos Spacecom, SES…) could also be considered if they develop mission tailored to the African region.

Development option selection

Recommended solution – SBAS payload hosted in an African-operated telecommunications satellite

Considering the international references, **the widespread model for the SBAS space segment is to host an SBAS payload in telecommunications GEO satellite, offering a cost-effective means to access satellite resources without the need of constructing and launching dedicated satellites**, an option that would significantly increase the costs of the SBAS programme. It would be **recommended to host the SBAS payloads in a mission owned and operated by an African entity, either private or public such as Rascom, Nigcomsat or Nilesat.**

9.3.2 SBAS Ground Infrastructure

Subsystem technical description

When evaluating the SBAS ground infrastructure, it's crucial to identify the individual components that make up the system. The primary elements consist of:

- RIMS (Reference Integrity Monitoring Stations): RIMS' main role is to collect data from GNSS satellites and transmit this raw information to the MCCs every second.
- MCC (Mission Control Centres): These centres receive data from the RIMS and produce correction and satellite status messages to enhance user integrity and accuracy. The MCC serves as the central control and decision-making hub for the SBAS system. The MCC is typically divided into two main subsystems
  - Central Processing Facility (CPF), in charge of generating the SBAS message
  - Central Control Facility (CCF), in charge of monitoring, control and data storage
- NLESs (Navigation Land Earth Stations): NLESs are responsible for transmitting SBAS messages generated by the MCCs to GEO satellites for broadcast to SBAS users and to ensure synchronization with the GNSS signal.
- Communications system: Wide-area network that enables communication among its ground segment elements

Current industrial landscape

There are several industry players with proven capabilities of developing and implementing complete SBAS systems.

- **Thales Alenia Space (Europe)**: Thales Alenia Space was the original developer of the EGNOS system in Europe, has been awarded the prime contractor role in the Korean KASS programme and has collaborated with ASECNA in the ANGA programme.
- **Airbus Defence and Space (Europe)**: Airbus is currently in charge of developing the EGNOS v3 evolution, aimed at providing Dual Frequency Multi Constellation (DFMC) capabilities in Europe.
- **Lockheed Martin (USA)**: Lockheed Martin was recently selected as the prime contractor to establish the SouthPan for the governments of Australia and New Zealand.
- **GMV (Europe)**: GMV is responsible for developing the CPF and CCF of the SouthPan SBAS and will also provide support to the systems' operation and maintenance.
- **Raytheon (USA)**: Raytheon was the original development contractor for WAAS and has continued working with the FAA on WAAS improvements since the system's certification. In 2022, Raytheon was awarded an additional contract to modernise system security, network architecture and adding Dual Frequency Operation. Additionally, Raytheon was also awarded the development of India's GAGAN.
- **NEC Corporation (Japan)**: NEC Corporation was chosen as the prime contractor for the MSAS programme in Japan.

No information regarding the SBAS contractors for the Chinese or Russian SBAS systems has been found.

<u>Current capabilities in Africa</u>

Currently, the ANGA (Augmented Navigation for Africa) project has developed an operational testbed to showcase its advancements in its SBAS Programme and drive adoption and acceptance of this technology in the African continent. The infrastructure deployed in the programme was:

- A set of GNSS reference stations (heritage of SAGAIE project completed by additional stations), locations illustrated in Figure 34
- A MCC system prototype deployed in Dakar using advanced correction algorithm and processing, optimized for ionospheric conditions in Africa.
- An uplink station (NLES) in Abuja.

The infrastructure deployment and system development were performed with the aid of CNES (Centre Nationale d'Etudes Spatiales), Thales Alenia Space and NigComSat, as the SBAS operational testbed was based on legacy EGNOS technology.

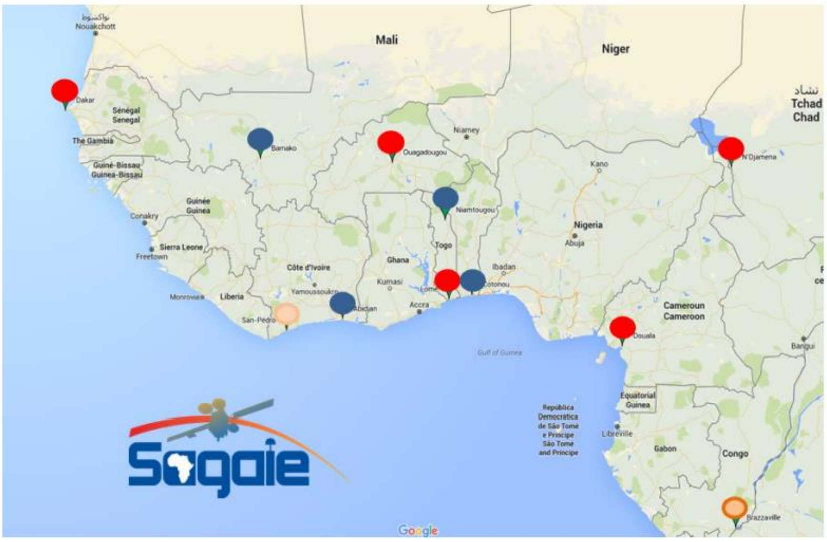


Figure 34: SAGAIE stations location - Source : ICAO

This has paved the way towards ANGA's SBAS initial non-operational services, which been broadcasted effectively on L1 band since September 2020, with compliance with ICAO SARPS sand RTCA DO-229 MOPs. This has been followed up by a successful DFMC demonstration in 2023, the first of its kind in any SBAS programme in the world.

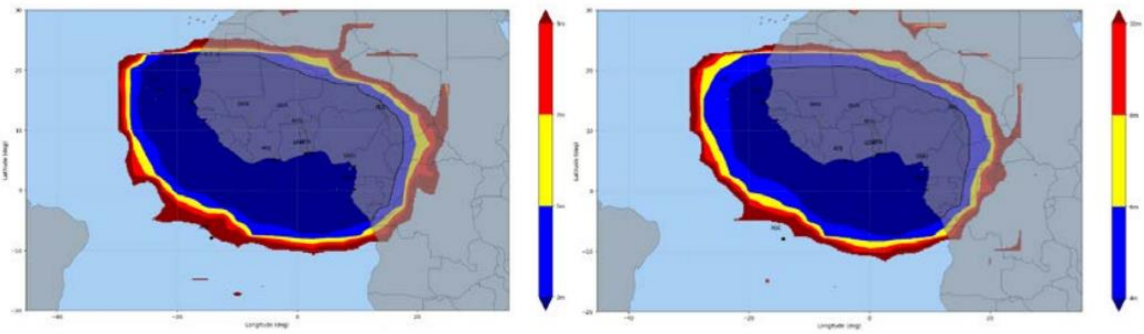


Figure 35: ANGA SBAS demonstration services - Source : ICAO

Using the APV-1 demonstration service in L1, a series of flight demonstrations were performed on January 27, 2021 at Lomé-Tokoin airport using the ASECNA ATR42-300, equipped for the occasion with a specific receiver and a specific navigation display, to fly the LPV approach and landing procedure designed for runway 22. These demonstrations showed the technical performance of the signal in real configuration and validated the demonstration infrastructure in a global approach. These results confirm the quality of the demonstration signal on L1, and thus the adequacy of the ionospheric models and the effectiveness of the advanced correction algorithms that have been developed.

A second series of demonstrations was successfully conducted on June 2, 2021, between Douala and Kribi in Cameroon with an AS365 N3 helicopter from Heli-Union. The helicopter performed a demonstration flight on a low-level route (LLR) linking two point-in-space (PinS) approaches (with LPV minima) at Douala airport and a point close to the oil platforms on the Kribi coast.

Finally, two demonstrations on ancillary services (beyond aviation) were also successfully conducted on July 7 and 8, 2021 in Brazzaville (Congo) with the A-SBAS demonstration signal on L5 providing an open service. The first one concerned the Emergency Warning Service (EWS) by satellite. It demonstrated the system's ability to broadcast an alert message via the A-SBAS demonstration signal to mobile phones, without requiring ground infrastructure. This service transmits an emergency message to the populations concerned, providing information on the type of hazard and the instructions to follow. The second was the transmission of GNSS correction by the A-SBAS demonstration signal to near-market user terminal prototypes for precise positioning applications (PPP).

This demonstrates African capabilities, in collaboration with international partners and based on existing technology, in successfully setting up the ground segment of the SBAS system and developing pre-operational services, a clear successful example of technological transfer.

On the other hand, EGNOS system currently has 3 RIMS deployed on the continent. The countries that count with these sites are Morocco, Tunisia and Mauritania. This is particularly valuable because there is already an existing a SBAS ground segment that could be utilized in the event of potential EGNOS v3 expansion to the continent, although implying a full technology import from third party

Figure 36: EGNOS RIMS sites
Source: EGNOS Safety of Life (SoL) SDD Issue 3.5

African stakeholders have therefore proven capabilities of developing (through technology transfer) certain of the elements that are necessary to develop and operate SBAS system and ground infrastructure. However, they are still reliant on third parties in terms of the system development and manufacturing, as there is no industry player in the continent current capabilities (nor in the short term) to develop the system independently.

<u>Development option selection</u>

Given the nature of what has been described above, it critical to analyse the value chain of the SBAS infrastructure and system to understand which of the elements along the value chain could be potentially subject to the different forms of development models

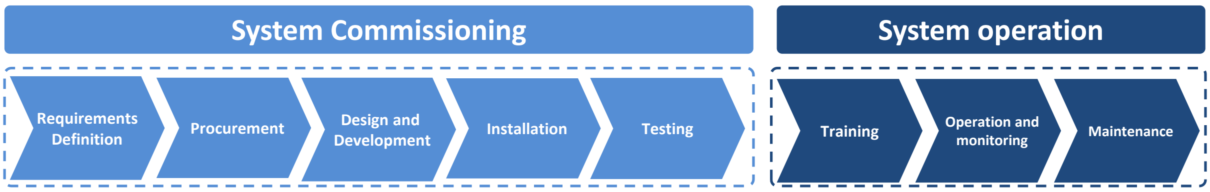


Figure 37: SBAS infrastructure value chain

The value chain is illustrated in Figure 37 and is divided into two main phases: system commissioning and system operation. The former is made up of the following main components:

- **System requirements and specifications definition:** Includes the detailed system design in terms of the definition of the user requirements, which are then traduced into the system's technical and functional requirements and technical specifications.
- **System procurement:** Includes project management duties (schedule, scope, quality, risk…) as well as the management of stakeholder relationships (industry suppliers, technical partners…)
- **System design and development:** Engineering activities regarding functionality development, interface description, performance evaluation and verification Manufacturing of the system's components, ensuring compliance with design specifications and fulfilling the requirements defined in the system design phase. This phase also includes factory acceptance testing.
- **System installation:** Execution of the physical installation of the systems at their final locations, including performing site surveys and selection
- **System testing:** Includes conducting comprehensive testing of the installed systems, identification of deficiencies and support to shadow mode and full entry into operations

After entry into operations, the following value chain components are identified:

- **Training:** Development of specialized training courses for the systems future operators
- **Operation and monitoring:** System operation to deliver SBAS services according to what is defined in the Service Definition Document. SBAS service monitoring and notification to users in case of any service degradation
- **Maintenance:** Provision of support for the installed systems through the implementation of a maintenance schedule and corrective and preventive maintenance processes.

Each subsystem is now analysed in full detail to select the most appropriate development model for each, considering the technical and economic implications, the current indigenous capabilities in the continent as well as the overall industry landscape, explained above.

Value chain component	Development model	Justification
System commissioning		

Value chain component	Development model	Justification
System requirements and specifications definition	Technological Transfer	As mentioned on Section 9.1, using proven technology in operational environments (high TRL) can lead to cost reductions of 300% to 400%. This can be observed from the cost comparison of the WAAS (over 3,000 million USD), EGNOS (over 1,000 million USD) with respect to KASS, which used EGNOS technology and has estimated costs of around 100 million USD. Given the funding difficulties highlighted in WP1, it is clear that Africa should leverage on existing SBAS technology. However, it is believed that to acquire valuable knowhow and develop indigenous capabilities, and following the example of KASS and ANGA, the design agent (entity with the responsibility for the system development, which could be merger with the Programme Manager) should be an African institution. A joint task force could be built between this design agent and international partners with proven capabilities (ESA, CNES, FAA…) to lead this first phase of system design. This involves jointly developing the user, functional and technical requirements that will drive the systems technical specifications.
Procurement	Independent, with support from third party	It is believed that the SBAS Programme Manager could lead the procurement phase of the programme, involving schedule, scope and risk management among other duties as well as communication with the industry contractors. However, it is believed that support from international partners could be necessary in terms of scope management, regarding any potential changes on technical aspects

Value chain component	Development model	Justification
Design and Development	Import from third party	In terms of the system development itself (engineering, production, factory testing, integration, verification…), it is recommended to select a contractor with proven capabilities, such as the companies presented above, even if this means delegating a part of the system development directly to a foreign entity. It is believed that this option will induce less programme risk (all initial SBAS programmes, EGNOS, WAAS and MSAS have incurred in significant schedule overruns). A possibility to induce the African aerospace industry could be including the requirement for the participation of African companies for certain elements of the system. This is not included in the main recommendation but be a potential option.
Installation and Testing	Independent, with support from third party	In terms of installation and testing, the recommendation is analogous to that presented in for procurement, with the SBAS Programme Manager leading the activities, with technical support from an international partner.
System operation		
Training	Support from third party	It is recommended that the prime contractor provides support in terms of training to the personnel that will be responsible for both the system operation and maintenance, transferring these capabilities so that the latter can perform these activities autonomously.

Value chain component	Development model	Justification
Operation and Maintenance	Independent	It is recommended that the day-to-day SBAS operations are performed by the SBAS Service Provider which should leverage on African indigenous capabilities after the transfer of know-how performed in the training phase

Table 17: SBAS ground segment development option selection

Recommended solution – Technology transfer with independence in key areas

The SBAS ground infrastructure and system is the most complex subsystem of the SBAS Programme. For this reason, a hybrid approach is recommended, based on the following pillars:

- **Technology Transfer** in terms of the overall system design, leveraging on existing technology to greatly reduce the development costs of the programme. The system design would be developed by a **Joint Task Force led by an African entity** (future Programme Manager / Design Agent) with the collaboration of international partners, that can provide experience and technical capabilities, following the example of Korea
- **The African SBAS Programme Managers** should lead the rest of the procurement phases, including installation and testing, with support from the partners
- The **system itself should be contracted to an experience international contractor** with proven capabilities, who will develop a system according to the specifications and requirements developed by the Joint Task Force. This is recommended in order to reduce programme risk. The SBAS Programme Manager could contemplate the requirement for the participation of African companies for certain elements of the system, such as the communications network, to increase the involvement of the African industry
- **The operation and maintenance** should be performed independently by the SBAS Service Provider, leveraging on the use of local personnel. Prior to this, a training stage should be performed in which the international partner, or industry contractor, transfers the capabilities to the future personnel

9.3.3 Airborne Equipment

This section differs slightly from the rest of the subsystems as the SBAS User segment is not under the control of the SBAS programme as it is driven by the end users, who ultimately have the decision on the installation of the equipment. This subsection will first describe the SBAS airborne equipment, as well as its main equipage trends and then examine the current industrial landscape to understand if it is of interest of the African SatNAV/SBAS Programme to promote acquiring indigenous capabilities in the SBAS airborne segment

Subsystem technical description and equipage trends in Africa

The SBAS user segment comprises all the user equipment that makes use of the SBAS Signal in Space (SIS). This includes an GNSS SBAS-compatible antenna, a GNSS SBAS compatible receiver and a Flight Management System (FMS) capable of processing the information received. The high-level configuration is shown in Figure 38

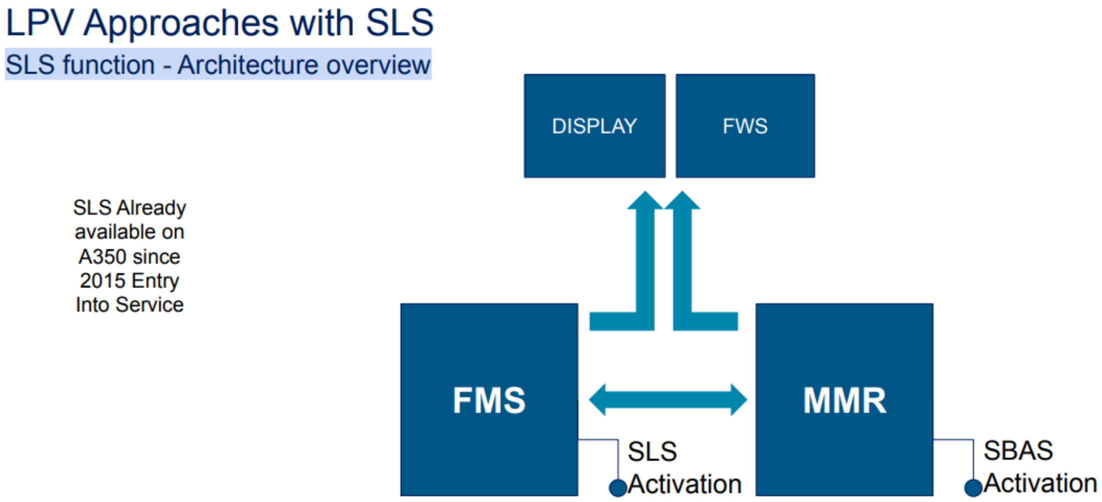


Figure 38: High-level aircraft SBAS configuration – Source: Airbus

For the Safety-of-Life (SoL) service, the SBAS user equipment shall be compliant (certified) against several standards. For instance, civil aviation SBAS equipment shall demonstrate:

- RTCA SBAS MOPS DO-229 (airborne equipment)
- RTCA SBAS MOPS 228 and 301 (antenna requirements)
- ED-259 MOPS for Galileo – GPS- SBAS Airborne Equipment
- ED-134 Signal Specification for SBAS L1/L5
- ED-157 SBAS L1/L5 ICD
- ETSO-C145e – Airborne Navigation Sensors using GPS augmented by SBAS
- ETSO-C146e – Stand-alone airborne Navigation Sensors Using the Global Positioning System (GPS) Augmented by the Satellite-Based Augmentation System (SBAS)

Additionally, at installation level, these systems must demonstrate compliance with respect to the interface description of the Flight Management Systems (FMS), which may imply different levels of retrofitting depending on the case.

As analysed in Phase I of the CBA, in between 2019 and 2021, around 5% of users declared SBAS capability (either LPV or MMR) in the analysed regions, mostly corresponding to ASECNA airspace, as illustrated in Figure 39.

- SBAS NAV/ADS-B: An SBAS-enabled multi-mode receiver (MMR) is used as a positioning source for ADS-B technology and/or to enhance navigation during the en-route phase but can't be used for guided approaches
- SBAS LPV: Capability provides vertical guidance to be used in RNP APCH LPV procedures

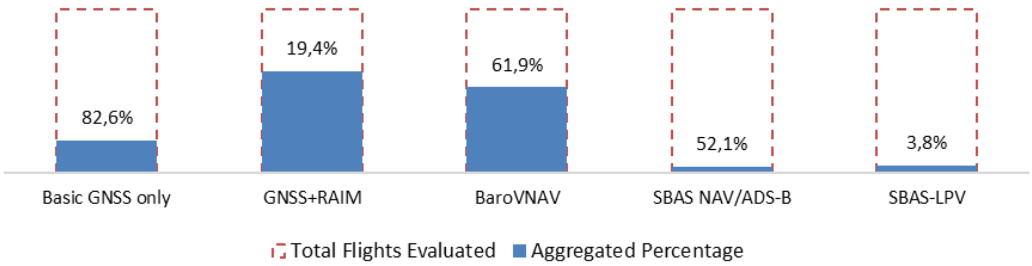


Figure 39: GNSS-based aircraft capabilities in African airspace

However, SBAS is gaining ground as more aircraft types become compliant, with steady growth in equipage from 2018 to 2021, as shown in Figure 40:

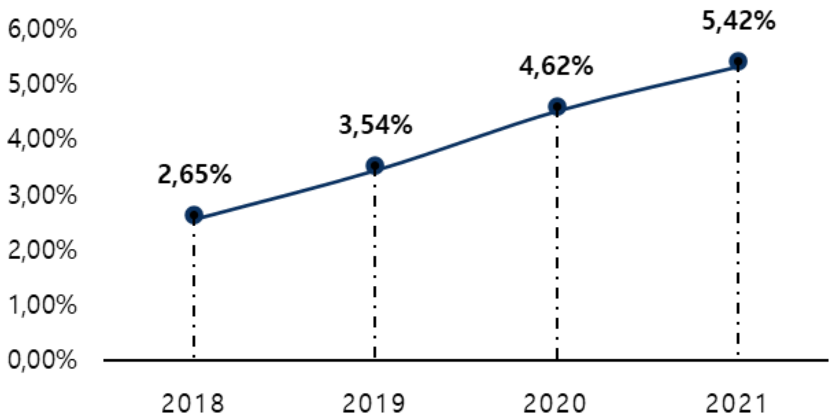


Figure 40: SBAS-LPV equipage rates in 2018-2021 in ASECNA airspace

Currently, most major aircraft manufacturers (Airbus, Boeing, Embraer and ATR) have SBAS available as an option on the newest models and there are retrofit possibilities for almost all existing aircraft. Additionally, the A220 has SBAS capability as a standard feature. All this leads to the conclusion that SBAS capabilities in airspace users are expected to grow significantly in the coming years and will rapidly increase when an SBAS service enters into operation in the continent.

For non-aviation users, they require SBAS-compatible GNSS receivers to enhance navigation accuracy in their different activities. In some cases, the standards to which they must adhere will be less stringent than for aviation users, with the latter requiring higher levels of integrity and accuracy.

Current industrial landscape

There are several established players, namely Rockwell Collins, Honeywell, CMC and Thales with multimode receivers and Flight Management Systems with SBAS NAV and SBAS LPV capabilities. For example, the compatibility of SBAS solution on the main Boeing aircraft models is included below, (For all Boeing airplanes, SBAS is currently available as an option, with no model currently including SBAS as a baseline feature):

Airplane model	Basic SBAS Positioning (MMR Output Type 1)		LPV (MMR Output Type 2)
	Honeywell	Collins Aerospace	
B737 Max	Available	Available	Available
B737 NG	Available	Available	Current Study
B 777	Available	Available	Not planned
B 777-900	Available	Available	Available
B747-800	N/A	Available	Not planned
B757/7676	Retrofit*	Retrofit*	Not planned
B787	Under current study	N/A	Current study

Table 18: SBAS compatibility of Boeing fleet – Source: Boeing SBAS & LPV Equipage presentation on SBAS Outreach Event – January 2022

For the case of Airbus, the latest information received by the STEs, dated January 2021, is included below (for both Collins Aerospace and Honeywell receivers).

Airplane model	SBAS MMR	SBAS LPV/SLS CAT I
A220 family	Standard feature	Standard feature
A320 family	Available	Available
A330 family	Available	Available
A350 family	Available	Available
A380 family	Available	Available

Table 19: SBAS compatibility of Airbus fleet - Source: EGNOS Workshop - March 2024

Likewise, ATR and Embraer have declared similar compatibilities with the major industry manufacturers. This means that there is already an established market, with competitive players that have developed solutions tailored to the main aircraft manufacturers (which concentrate the vast majority of aircraft sales to African airspace users)

Development option selection

Recommended solution – End-users purchase solutions from third party

Airborne equipment falls outside the scope of all operational SBAS Programmes in the world.

The SBAS airborne equipment market is largely dominated by private parties, which have solutions integrated in all the main aircraft models, which operate in a highly competitive market. As the selection of the SBAS airborne equipment **is driven by the users**, they will have the ultimate choice of selecting the solution which best fits their needs.

It is therefore recommended not to explore acquiring indigenous capabilities in this market, as it will be difficult to compete with the private players in the market, and it is not considered to be of significant added value in comparison with the ground segment.

10.Transfer of Technology Agreement

Section 2 has led to the recommendation of a technology transfer in terms of the core of the SBAS design. A deeper analysis is necessary to understand how this technology transfer agreement could be structured.

General provisions

This section would define all the introductory elements to the transfer of technology contract, including the aim of the collaboration, the main definitions as well as the cooperation and transfer of technology principles.

Scope of collaboration

Definition of the extent up to which the partner entity will assist the SBAS Programme Manager / Design Agent in the development of the SBAS system. As outlined in the section above, this could include the following categories.

Definition and design of the system

This could include support in the definition of the user, functional and technical requirements for both single frequency and DFMC as well as support in the site selection process. A particular interesting area of collaboration could be the adaptation of the SBAS system to the ionospheric environment of Africa, more affected by the phenomenon of scintillation due to its proximity to the Equator in comparison with other operational SBAS systems, with service areas of higher latitude. Additionally, support could be provided in the RIMS site selection process

Procurement

This section could include the definition of the activities where the partner could collaborate on during the tender stage (tender preparation, review, setting award criteria, competitor evaluation…). Other activities could include to control any possible deviations in scope as well as verifying all technical requirements of the system are met during the On-site Acceptance Test (SAT) and System Integration Tests (SIT).

Certification

Assistance to the SBAS Programme Manager in the certification of the SBAS system and services in terms of the necessary steps to be taken.

Radiofrequency management

Assistance towards the protection and allocation of frequency bands linked to satellite navigation services and aviation communications by ITU (International Telecommunication Union) to ensure accessibility of services to be offered by SBAS in Africa

Operations preparation

Assistance in the preparation of entry into operations of SBAS services. This could potentially include definition of steps towards declaration of services, assistance in the development or review of the Service Definition Document and Working Arrangements, development of operational manuals, as well advice in any security and safety aspects related to service provision. It is important to highlight that **the Service Provider will have ultimate responsibility of the SDD, Working Agreement and operational manuals, regardless of any support in their development.**

Collaboration could also potentially include providing assistance during the shadow mode and initial entry into operations, resolving any operational problems encounters subsequent to the declaration of services, jointly developing or proposing processes and tools to monitor service and system performance as well as defining processes to provide information of end users (i.e NOTAMs)

Capacity building

Assistance in the capacity building process towards the operationalization of SBAS. This could include:

- Development of joint research and development activities in satellite navigation, aimed towards future technological advances in SBAS systems.
- Training of the African SBAS Provider personnel that will operate and maintain the system
- Conduct joint communication and promotion activities (workshops, webinars, demonstrations) to support user uptake in Africa

Intellectual property rights

This section would include any clauses regarding the intellectual property rights of the entity transferring the technology (“owner”) and the SBAS Programme Manager. The clauses should include but not be limited to:

- Subject of the intellectual property (what is included, for example database, software…)
- Licensing (exclusivity, right of transmission…)
- Right of use (reproduce, adapt, manufacture…)
- Property rights of any new development made by the SBAS Programme Manager thanks to the original property rights of the “owner”
- Duration

It is proposed to configure the arrangement so that the technology “owner” becomes the holder of any new property rights generated through the use of its technology by the SBAS Programme Manager, with the latter having a free license to use these new rights.

Funding

This section could define the extent and the mechanisms that will be set up for the funding of certain activities included in the collaboration agreement (research and development, joint promotion activities…).

Other provisions

Other provisions in the agreement could include the creation of committees between both partners to monitor and govern the agreement, clauses regarding legal responsibility and liability (or lack of) of the two entities regarding the services to be provided, settlement of disputes, entry into force, amendments and termination.

11.Risk Identification and Management Plan

The chosen scenario presented above has a series of associated risks. A preliminary quantification of risks will be performed to provide a high-level overview of the main risks to solve and the main mitigation actions.

Risk management can be defined as the forecasting, assessment and monitoring of risks together with the identification of procedures, measures and steps that can be taken to avoid or to minimise their impact on the contract execution. Risk management processes cover:

1. **Risk identification**: identification of nature and origin.
    a. **Technical**: those risks associated with the correct development and delivery of the project, according to the defined technical scope, that might lead to technical challenges hard or even impossible to solve within the project's context.
    b. **Cost**: those risks directly associated with extraordinary increases of the expected costs; and
    c. **Schedule**: those risks directly associated with extraordinary increases of the expected completion time of the project.
2. **Risks Assessment**: analysis of the following parameters.
    a. **Likelihood** (qualitative or quantitative) of the risks.
    b. **Severity** (qualitative or quantitative) that would result if those risks happened.
    c. **Criticality**, which is defined as a combination of likelihood and severity, a classification that intends to provide each risk with a unique priority indicator.

Criticality		Likelihood				
		1	**2**	**3**	**4**	**5**
Severity	**1**	1	2	3	4	5
	2	2	4	6	8	10
	3	3	6	9	12	15
	4	4	8	12	16	20
	5	5	10	15	20	25

Criticality=1	1<Criticality≤5	5<Criticality≤10	10<Criticality≤20	Criticality>20

Figure 41: Risk criticality matrix

3. **Planning of a response for control and mitigation**: identification and assessment of different alternatives
   a. **Risk avoidance**: taking steps to ensure that risks are eliminated from the outset.
   b. **Risk mitigation**: the inclusion of a set of measures aimed at reducing the likelihood and/or the severity of risks; or
   c. **Risk acceptance**: in specific circumstances, the Team will agree with the DG DEFIS to share (gross or residual) risk.

11.1.1 Risk Identification and Mitigation Strategies

The SBAS Programme risks are dependent on the subsystem as well as the development option selected in the previous section. A breakdown per system segment is performed:

Space segment

The main risks of the space segment development and operation are based on the fact that the SBAS space payload will be hosted as an element of another primary mission (typically telecommunications), which will bring elements of dependency with respect to the satellite operator, who may not be a part of the programme. The following risks are identified:

Risk name	Risk description	Likelihood	Severity	Mitigation action
Dependency with third parties (development stage)	As the SBAS payload will be hosted as a secondary payload on a satellite mission, there will be a level of dependency on the corresponding mission (mainly in terms of schedule), as any change in the overall mission would affect the SBAS Programme	Moderate	Low	Partnership with the satellite operator so that it becomes a partner in the SBAS Programme, increasing the level of commitment with the SBAS Programme and roadmap
Dependency with third parties (operational stage)	Relying on external satellite operators creates a dependency on their services, making the SBAS system vulnerable to potential disruptions in case of problems (personnel or technology related)	Low	High	Partnership with the satellite operator so that it becomes a partner in the SBAS Programme, increasing the level of commitment with the SBAS Programme and roadmap
Limited experience in satellite operation	Indigenous development entails ongoing operational responsibilities, including satellite monitoring, maintenance, and troubleshooting, which can be challenging for a region with limited experience in satellite operations.	Low	High	Selection of a satellite operator with ample and demonstrated experience in the field

Table 20: Space segment development risks

Airborne equipment

As it is recommended to procure the systems from established airborne equipment providers (Collins, Honeywell…), all technical (compatibility, integration) and regulatory risks are mitigated. The risks identified are more related to the users and their acceptance towards SBAS technology as well as their capacity to equip their fleet:

Risk name	Risk description	Likelihood	Severity	Mitigation action
User acceptance	Users are not knowledgeable regarding SBAS technology and the benefits it provides, and are reluctant to equip their fleet	Moderate	High	The Market Development Agent of the African SBAS Programme could perform promotion campaigns, SBAS demonstrations and specific business cases to help raise awareness on the benefits of the technology
Fleet readiness	African airlines do not have SBAS capabilities in their aircraft by entry into operations	Moderate	Low	No direct mitigation actions. It is expected for equipage rates to increase organically over the next decades, due to mandates in other regions and increased "SBAS options" or standard features on aircraft
Financial capabilities	African airlines do not have the means in order to invest in SBAS receivers and FMS updates	Moderate	Moderate	Financing programmes, perhaps under multilaterals such as the African Development Bank, can help airlines finance their investments related to SBAS, perhaps under the coordination of the Market Development Agent

Table 21: Airborne segment development risks

Ground infrastructure and system

The proposed model, involving a certain degree of transfer of technology and collaboration is expected to mitigate several of the technical risks related to the ground infrastructure. The following risks in the development and operational phases are identified:

Risk name	Risk description	Likelihood	Severity	Mitigation action
Development Phase				
Delays in system procurement or other activities	Delays occur during the system development, installation, testing phase or training phase, leading to a late entry into operations	Moderate	Low	Realistic schedule development during tender preparation phase, with the aid of international partners Careful project management during procurement phase Selecting a prime contractor with demonstrated capabilities in SBAS system development

Risk name	Risk description	Likelihood	Severity	Mitigation action
Cost overruns	The programme costs increase over the expected budget	Moderate	Moderate	Realistic cost estimation during tender preparation phase, with the aid of international partners Selecting a prime contractor with demonstrated capabilities in SBAS system development
System integration problems	Problems arise during the System Integration Testing, potentially due to subsystems coming from different providers or other	Low	High	Selecting a prime contractor with demonstrated capabilities in SBAS system development Selecting subcontractors with demonstrated capabilities in their areas of expertise
Inadequate system performance	The system is not able to provide performance according to ICAO standards	Low	Critical	Selecting a prime contractor with demonstrated capabilities in SBAS system development
Sensitivity to ionospheric disturbances	The system's performance in degraded under acceptable performance levels in periods of high ionospheric activity	Moderate	Moderate	Developing an atmospheric scintillation model appropriate for the ionospheric conditions of equatorial Africa Adequately monitoring the system's performance levels and alerting user of any potential degradation
Inadequate Service area	The resulting service are does not cover all the intended geographical area	Low	High	Performing an exhaustive site selection and inspection process and a detailed analysis anon the expected service areas according to the placements of the RIMS. Size and design the system to follow industry best practices regarding error tolerance levels (potentially translating to a denser RIMS network or additional stations in the outskirts of the intended service area
Operations phase				
Disruption in operations	Disruption in operations caused by power outages or communications failures	Low	High	Ensure redundancy in all system layers, avoiding single points of failure

Risk name	Risk description	Likelihood	Severity	Mitigation action
Personnel problems	The personnel of the SBAS Service Provider do not have the capabilities to operate and maintain the SBAS system correctly	Low	High	Capacity-building exercise prior to entry into operations based on a training programme by the international partners involved in the programme or by the contractor

Table 22: Ground segment development risks

11.1.2 Risk Management Process

The risk management process outlines the steps that have to be followed during the programme execution phase to ensure that all risks are properly identified, classified and that an appropriate action is taken.

The proposed risk management process is derived from NASA's Risk Management Handbook and is based on the Continuous Risk Management (CRM) principle. The CRM process manages risk by identifying specific issues that are of concern to one or more stakeholders, and which are perceived as presenting a risk to the achievement of performance requirements.

Figure 42: Continuous Risk Management Stages - Source: NASA

The CRM process encompasses five recurring stages: **Identify, Analyse, Plan, Track, and Control**. These stages function concurrently, allowing for the simultaneous reporting of individual risks into the risk database, incorporation of risks into the risk model, development of risk response plans to mitigate performance risk, and tracking and controlling of implemented risk responses. The CRM process is shown in Figure 43:

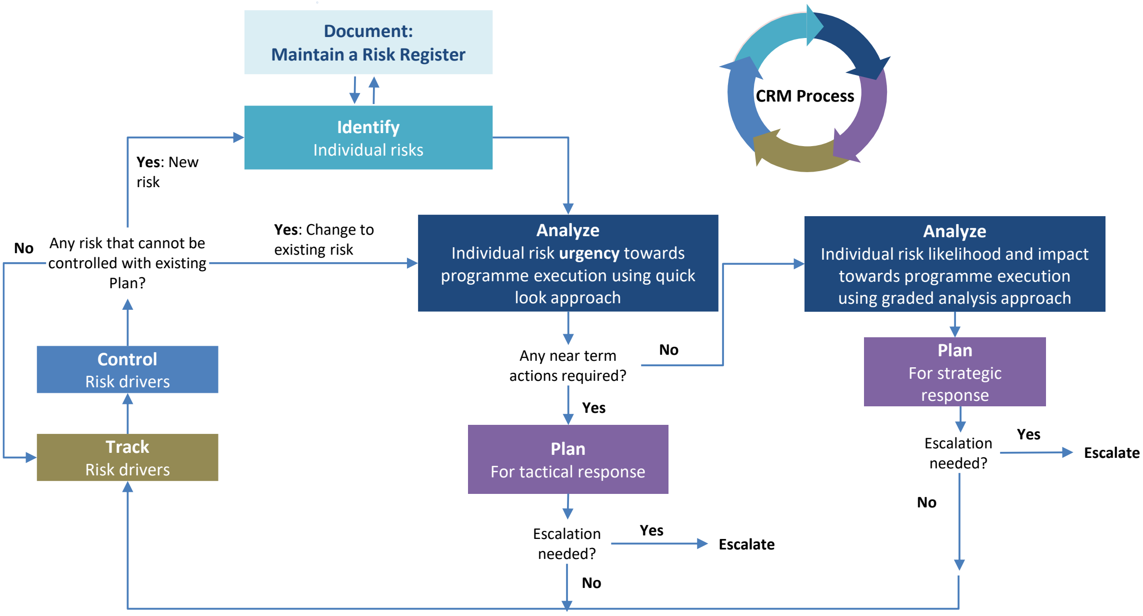


Figure 43: Risk management process - Source: NASA

Beginning with the Identify step, individual risks are generated, due either to their prior identification or to their identification during implementation A quick analysis is conducted to assess their urgency, and urgent risks are promptly forwarded to the Plan stage for timely response implementation. Non-urgent risks undergo detailed analysis before planning to ensure that the planning process is well-informed by a robust analytical basis, facilitating the selection of effective risk responses. In either case, the risk register is updated with the selected risk response, and the risk drivers are tracked and controlled as necessary to keep performance risk within tolerable levels.

If there are insufficient resources at the current level to execute an effective tactical or strategic response, the risk decision is escalated to the next higher organizational unit.

To manage this complex process in the SBAS programme, a series of risk-management committees are proposed, illustrated in Figure 44.

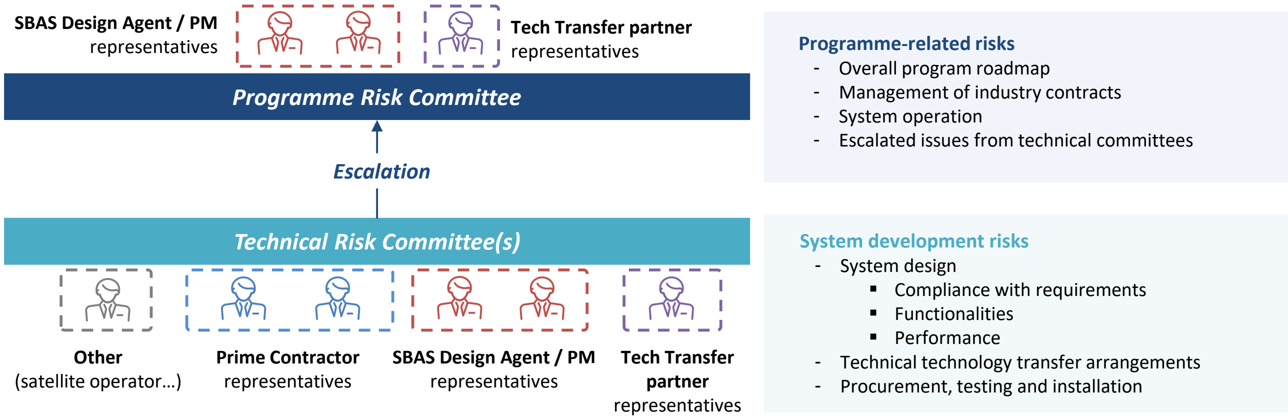


Figure 44: Risk management committees

First, a technical risk committee, formed by representatives of the prime contractor, the SBAS Design Agent / Programme Manager and Technological Transfer Partner, as well as other representatives upon need (i.e. satellite operator) would deal with the identification, assessment, tracking and monitoring of all risks related to system development, focused on technical aspects (compliance with requirements, system performance, procurement…). Any issue that cannot be responded to will be escalated to an upper echelon, the Programme Risk Committee, as indicated in the CRM process.

This Programme Risk Committee would be formed by members of the SBAS Design Agent / PM and the Technological Transfer partner (although representatives from other entities could be invited upon need). They will be tasked to resolve the escalated issues from the technical committees, as well as perform the complete CRM process for other strategic topics key to the programmes' development, such as deviations to the roadmap, management of industry contracts... Finally, they will also be tasked to deal with the risks related to the operation of the system after entry into operations.

This risk management process and governance framework aims to provide a sound methodology in order to identify, assess and respond to all the risks that may come up in the development of SABS capabilities in Africa.

12. Key Takeaways from Virtual Validation Workshop

The SBAS CBA Phase II Stakeholder Validation Workshop welcomed a good participation with 106 Participants connected via zoom from AU Member States, regional organizations and key partners in the area of SBAS (EAC, COMESA, ECOWAS, and international organizations (ICAO, IATA, ASECNA, SATNAV JPO, EASA).

- The Consultants delivered 2 presentations on Task 1 covering Organization and Institutionalization Studies, and Task 2 covering Technology Transfer and Risk Assessment for the continental CBA study on SBAS. The presentations were followed by a session of questions and answers as well as presentations and experience sharing from Member States and partner institutions
- Phase I of this Cost Benefit Analysis, centered on the economic attractiveness of SBAS at a continental level, was conducted throughout 2021-2022, and its results presented in the SBAS Continental Workshop, in Kigali in May 2022. As part of the next steps of the Continental Workshop, there was a call to prepare a study on institutionalization
- The 4 th Ordinary Session of the Specialized Technical Committee on Transport, Transcontinental and Interregional Infrastructure, and Energy (STC-TTIIE) meeting held in Zanzibar-Tanzania from 12 to 15 September 2023, further instructed AUC, AFCAC and ICAO to coordinate the finalization and adoption of the continental CBA Study on SBAS and implement its recommendations

KEY RECOMMENDATIONS

<u>Institutionalization</u>

1. The meeting noted the SBAS Model Options which were discussed, and recommended the model combining the following 3 approaches:
    a. Public Ownership approach - where African countries have full control over the system and its roadmap.
    b. Single or dual organizational approach – the consultants highlighted the single organizational approach where all functions will be in one organization that can take up associated complex management and operational functionalities. The meeting also considered the dual organizational approach where a separate service provider introduces a level of separation and specialization in the management and operations.
    c. Hybrid Centralisation approach – The meeting considered the Hybrid centralisation as the preferred option to continental or regional approaches. A central entity provides a common policy and governance platform, unified regulatory framework and service levels defined in terms of functionalities such as strategic direction, oversight, regulation, and market development.

2. Consultants recommended the establishment of a Continental Policy Body – where a single policy-making body within the AU would set general policies and an overall African SBAS Program roadmap, providing oversight over individual SBAS programmes. It would also push for continent-wide standards for SBAS performance, ensuring consistency in service quality and reliability and seamless operation of SBAS users between different SBAS regions
3. The meeting also considered the option to adopt a Phased and Modular Approach:
    a. It was explained that a phased approach allows for the development of SBAS capabilities in stages, starting with regional systems to allow groups of countries to move towards SBAS implementation with a certain degree of independence.
    b. It was recommended that a single oversighting body, will unify these regional SBAS systems initiatives with the aim to form a comprehensive, continent-wide interoperable SBAS, ensuring that aircraft can seamlessly transition between different airspaces without losing SBAS service;
    c. Either multiple SBAS programmes could be developed, coordinated under the African SBAS Programme, or one or two programmes could progressively expand its scope across the continent.
4. Institutional roles: Key institutions were identified and allocated key roles as follows:
    a. AfSA - To ensure alignment with continental policies and goals through AUC space policy and strategy guideline with regards to Satellite Navigation Component
    b. RECs – To support AfSA and act as a liaison between the African SBAS Programme and the Individual SBAS initiatives, contributing to the African SBAS Programme's policies
    c. ICAO, AFCAC and the RSOOs – To support AfSA by ensuring regional planning, regulatory harmonisation and certification
    d. SatNav Africa JPO – To act as the SBAS Market Development Agent for the African SBAS Program, focusing on driving market adoption and stakeholder engagement across the continent
5. Political and financial support: The political layer of the African SatNav Programme should be funded through mechanisms typically used by AfSA, while individual SBAS Programme leaders would cover their initiatives independently using public funds, multilaterals, and grants
6. Roadmap for African SatNAV Programme: Roadmap for African SatNAV Programme – The meeting considered the following roadmap elements
    a. 2024 -2025: Creation of the African SatNAV Programme under AfSA

b. 2026 – 2027: Drafting of common policies, a harmonized regulatory framework, development of oversight capabilities and integration of the JPO into the African SatNAV Programme

c. 2025-2034 : Development of individual SBAS initiatives – i.e consider evolution and expansion of current and any new initiatives including ANGA and EGNOS v3.

Technology Transfer

The meeting noted the following key technology transfer considerations:

1. Benchmarking Space, Ground and Airborne equipment subsystem against international practices.
2. Leveraging on proven technology with the aid of an international third party. The technology transfer arrangement was considered to be the most suitable system development alternative for African SBAS, as it will allow African stakeholders to gain certain capabilities and expertise in the area, while ensuring the technological feasibility of the programme, with the help of an experienced international contractor.
3. The meeting considered the need to develop a transfer of technology agreement to coordinate the collaboration with the international partner. The agreements include the issue of Intellectual Property Rights.
4. The meeting considered risks associated with SBAS technology transfer and recommended setting up a Technical and Programme Management Committee with the task of identifying, assessing and monitoring the main programme risks, with the participation of all key stakeholders.
5. The meeting considered the need for promotion campaigns to demonstrate the benefits of SBAS technology to raise awareness on the benefits of SBAS to African airlines and explore incentivization mechanisms, to drive fleet readiness.
6. It was agreed that there is need for investment in local talent and technology is crucial for the long-term sustainability of SBAS services in Africa. Developing a skilled workforce within Africa ensures that the continent is not perpetually dependent on external experts for the operation and maintenance of its SBAS. Key Workshop Recommendation

Workshop Recommendations

1. Consider the role of relevant ICAO PIRGs for institutionalization, planning and implementation of SBAS technology in Africa.

2. Consider the need to develop a robust framework for certification of SBAS equipment and operations and also consider capacity in the continent for such tasks.

3.After consideration of the comments made during the workshop for the SBAS final report, AUC and AFCAC were requested to submit the outcomes of the continental Phase II CBA

CONCLUSION

The meeting noted the report as presented by the consultants concerning the institutionalization encompassing programme governance, organisation, funding and technology transfer requirements and options for SBAS Implementation in Africa. It was agreed that the AUC and AFCAC should proceed to present outcomes of the Phase II CBA study to the next AUC STC meeting