International Civil Aviation Organization
South American Office (SAM) - Project RLA/03/902
Transition to GNSS/SBAS in the CAR/SAM Regions –SACCSA **-** *Phase III*
Ninth Meeting of the Coordination Committee (RCC/9)
Lima, Peru, 1-4 July 2013

Agenda Item 2: **Report of the activities conducted to date since the Eighth Coordination Meeting and status of implementation of Work Packages**

GNSS-SBAS Worldwide

(Presented by the Secretariat)

SUMMAY	
This working paper presents a summary of the international context and evolution of SBAS. The purpose of this paper is to provide a global picture to supplement the CAR/SAM perspective.	
Strategic Objectives	*This working paper is related to Strategic Objectives:* *A. Safety* *C. Environmental protection and sustainable development of air transport*

INTRODUCTION

This working paper presents a summary of the international context for SBAS and its evolution. The purpose of this paper is to provide a global vision to supplement the SACCSA perspective.

GNSS WORLDWIDE

The current satellite navigation systems include global systems (GPS, GLONASS, Galileo, Beidou), regional systems (SBAS, QZSS, COMPASS, IRNSS) and local systems (GBAS, hybrid systems combining GNSS and other sensors). The use of GNSS in safety-of-life applications and, consequently, for PBN implementation (performance-based navigation) requires a certain level of confidence on the positioning of the equipment. This is possible by supplementing the signals of global satellite navigation systems with other systems or techniques to produce a solution with the required integrity.

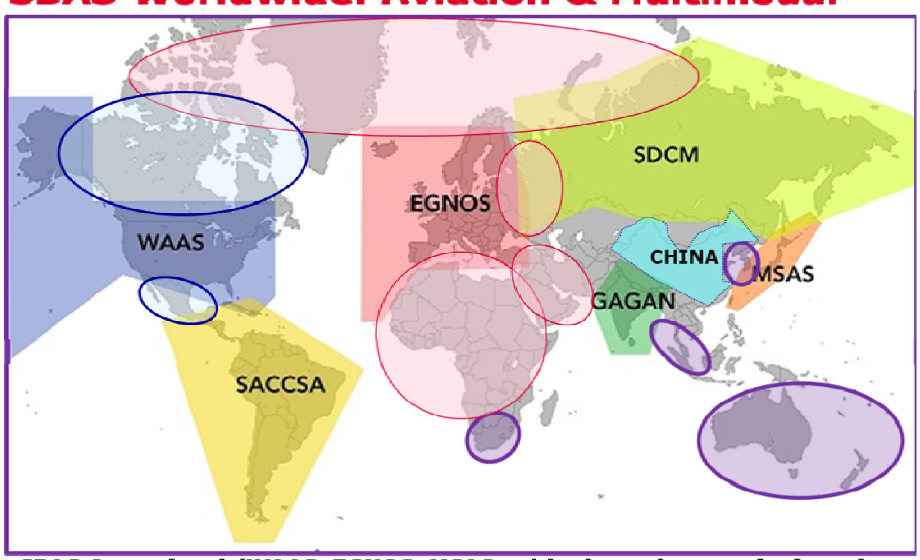
One of the main challenges facing civil aviation is PBN implementation. GNSS technology (ABAS, SBAS, GBAS, etc.) is a key element to achieve this objective. SBAS systems represent an important development in air navigation aids, especially for approach and landing, enabling LPV 200 services equivalent to ILS CAT I, all without the need for ground airport infrastructure, and can be implemented at any airport.

In the aeronautical community, SBAS is recognised worldwide and is considered by ICAO as a navigation aid reference. ICAO has developed PBN and the ASBUs, establishing an international calendar for approaches with vertical guidance (LPV) to reduce CFIT and thus enhance safety worldwide. The objective is to have LPV in all instrument runways, as primary or backup, for precision approaches by 2016. Most countries are developing their PBN implementation plans to comply with ICAO recommendations, and the use of SBAS is recognised as one of the most appropriate solutions. These systems are based on the use of GPS augmented by signals transmitted through GEO, which has the advantage of covering broader areas.

The systems that have been developed to date are WAAS, MTSAT (only for NPA and APV I), EGNOS in Europe; systems in the final development phase are GAGAN in India, SDCM in Russia, and COMPASS in China; and SACCSA is in the definition and demonstration phase. Furthermore, there are initiatives under way in other regions of the world, like in Africa, both at ASECNA level and in South Africa. There are also initiatives in East Europe, in the Arctic region and in the MID Region, and in several countries of Asia.

The following figure illustrates the regions of the world where systems have already been deployed, are in the development phase, or in the study phase. The area covered is quite broad, which reflects the interest in SBAS all over the world and the explosion of initiatives in recent years.

SBAS Worldwide: Aviation & Multimodal



SBAS Operational (WAAS, EGNOS, MSAS, with planned expansion), under development (SDCM, GAGAN) and feasibility studies

In recent years, there has been a true **explosion of the GNSS** all over the world as a result of the proliferation of new navigation systems currently in operation or in the deployment phase, such as GLONASS, Galileo and Beidou, the modernisation of the existing ones (GPS L5) and augmentation systems that enhance precision, integrity, availability, and continuity, such as ABAS (RAIM, ARAIM), local systems such as GBAS, and regional SBAS systems. Additionally, high-precision techniques, such as RTK and PPP are a clear trend in the multimodal sector.

Regarding GNSS evolution, multi-constellation and multi-frequency are aspects that clearly mark the evolution of these systems, significantly improving the services provided and thus their operational benefits. Regarding multi-constellation, the mandate of Russia to regulate the use of GLONASS in the Russian airspace and the conclusions of the ICAO ANC/12 meeting (Montreal, November 2012) in this regard through recommendations 6/5, 6/6, 6/8, 6/8, and 6/9 have been determining factors in the past year.

Both multi-frequency and multi-constellation are aspects that clearly benefit equatorial regions, such as the CAR/SAM Regions, and will largely mitigate the limitations imposed by the ionosphere in these regions of the world. The solution proposed in SACCSA considers these two factors as critical for the long term, but also intends to benefit from the SBAS in the short/medium term. There is some controversy as to when this technology would be operational for use in aviation, estimating that it would be fully operational around 2025/2030 (global GNSS, aviation system, avionics, and aircraft retrofit). Accordingly, the existing evolutionary plans for multi-frequency and multi-constellation consider maintaining the legacy mono-frequency L1 service at least until 2030.

SACCSA SBAS SOLUTION

As already discussed, in equatorial regions such as the CAR/SAM Regions, the main problem for SBAS is the ionosphere. A huge effort has been made to thoroughly study ionosphere behaviour in these regions and its impact on GNSS, particularly on SBAS systems. It has been necessary to adapt the ionosphere models applied in medium latitude regions—for which SBAS systems were initially designed—but without modifying the standards, in order to make SACCSA fully interoperable with WAAS and EGNOS, and to allow any SBAS receiver to operate in the region. In general, the main strategy has been first to analyse the problems, understand the situation in the CAR/SAM Regions, its requirements, the environment (not only in technical terms), and then identify possible solutions maximising the cost-benefit ratio. The proposed solutions were based on an innovative and open-minded vision, analysing the problem from the user's point of view.

In order to maximise the cost-benefit ratio, in addition to providing benefits to aviation, the proposal is to take advantage of the SACCSA technology in other multimodal sectors. SBAS systems are driven by aviation, since this user community that has the most stringent requirements, but they are used in many other sectors.

As to the services and operational benefits expected from SACCSA, the assumption is that it is an SBAS L1 system that provides APVI/LPV200 services, depending on the region, ionosphere conditions, and the solution implemented. The proposed solution is a system also intended for multi-frequency and multi-constellation, so that when the technology is available on the aircraft, the services provided would improve significantly, reaching CATI/CATII with multi-frequency and multi-constellation.

SBAS BENEFITS AT GLOBAL LEVEL

ICAO is strongly relying on GNSS implementation as one of the pillars of its strategy, reflected in the PBN and ASBUs, on which almost all the regions of the world are working. This strategy includes large ATM programmes, such as NextGen in the United States (based on WAAS) and SESAR in Europe (based on EGNOS).

ICAO has identified multiple benefits from the use of SBAS at global level, including:

Technical benefits:

- Enhanced air navigation safety
- Reduced CFIT (controlled flight into terrain)

- Instrument approaches with vertical guidance (LPV, APV)
- Reduced decision height in approaches to airports where only non-precision instrument approaches are currently available
- More flexibility in terms of routes and approach procedures, without the need for local infrastructure or large investments in avionics
- Fuel savings
- Reduced CO2 emissions
- Avoids flying over certain areas/regions for environmental, noise, security and other reasons.

- Reduction/elimination of ground infrastructure (reduction of ILS, DME and elimination of NDB and VOR), thus reducing infrastructure and maintenance costs (including periodic calibration flights).
- ADS-B improvement/support

- Technical benefits not only for civil aviation: improved precision, availability of the GNSS service, providing integrity/reliability to the solution.
- The SBAS technology does not require additional local infrastructure, and can service remote areas (geography, terrain, security, non-instrument airports, etc.)

Operational benefits:

- Facilitates air navigation (RNAV) in all flight phases
- Easier access to airports by all aviation segments (including general aviation)
- Enhanced air navigation safety
- Increased airspace capacity (*e.g.,* smaller route separation) and airport capacity
- Operational improvement of approaches to airports. Better access to airports under adverse weather conditions (due to a reduced decision height)
- Fuel savings, reduced emissions and noise pollution (due to flexible route design and instrument procedures)
- Avoids flying over certain areas/regions for environmental, noise, security and other reasons.
- Less delays, deviations to the alternate, and cancellations and, thus, provides operational savings to airlines.
- SBAS interoperability. This is a key aspect worldwide to ensure the incorporation of such technology at different operational levels. It is essential for SBAS systems to be interoperable so that airlines may operate in different regions of the world using the same avionics.

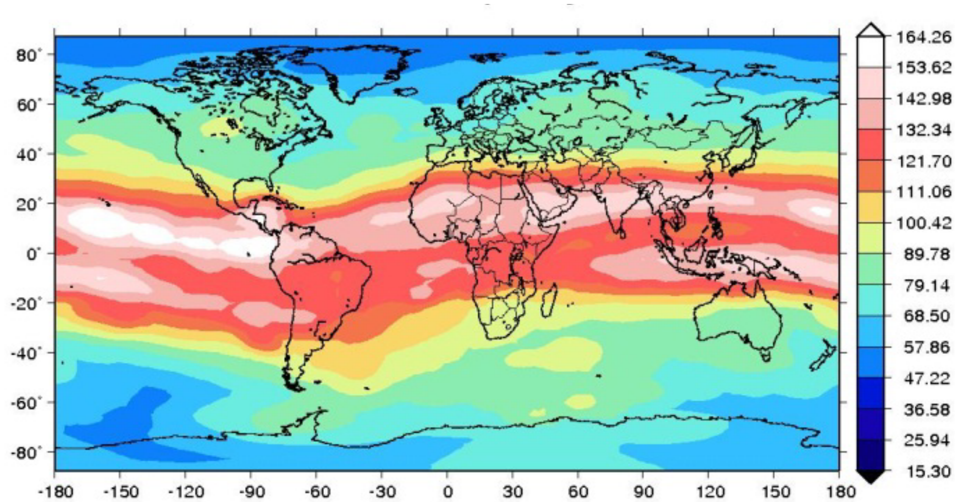
Although the aeronautical community has defined the SBAS (requirements), most of its users are not from aeronautical world. The SACCSA SBAS would provide benefits not only to aviation but also at multi-modal level in key sectors that are critical for the States: mining, energy, public works, agriculture, river and maritime navigation, general aviation (jets, helicopters, etc.), military, security, law enforcement, border control, enabling high-value services/applications: services, technological industry, spatial sector.

THE PROBLEMS OF THE CAR/SAM REGIONS

All systems are subject to disturbances to a greater or lesser extent, the most complicated and severe being those caused by the ionosphere. In this regard, there are various solutions, from “broad spectrum” Klobuchard-type algorithms (which do not include integrity, so must be used with autonomous RAIM-ABAS integrity algorithms and are initially applied in most systems) to dedicated algorithms to solve regional/local issues, such as the ionosphere models developed in WAAS and EGNOS. These models are valid only for regions in medium latitudes, and are not recommended for equatorial regions. Specific ionosphere algorithms/models have been developed for equatorial regions, based on their ionosphere characteristics. This has been done in both GAGAN and SACCSA.

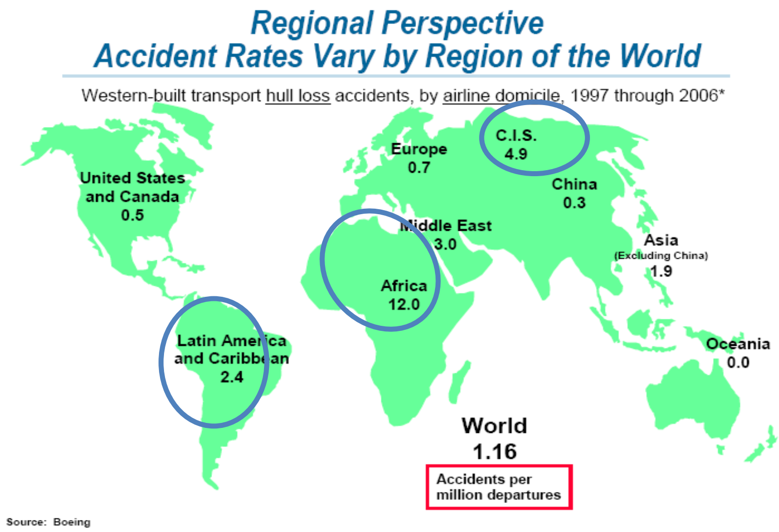
The SBAS and GBAS systems are especially vulnerable to the equatorial ionosphere, since they were initially developed for medium latitudes. The following figure, obtained within the framework of the SACCSA project, shows the maximum ionospheric value (in TECUs) for the previous solar cycle (3 days per month for 12 years). The figure clearly illustrates the problem of the ionosphere all over the world and in the various regions. As a general rule and from a qualitative viewpoint:

- Regions in red are equatorial ionosphere regions (with respect to the geomagnetic equator) where GNSS systems (SBAS and GBAS)--designed and developed for medium-latitude regions--will have significant limitations. It is essential that they are adjusted to the equatorial ionosphere; even their technical feasibility may depend on that.
- Regions in orange and yellow might have problems--depending on their design--during periods of high solar activity (like the one that is now starting).
- Regions in green and blue are considered to be medium latitude regions and no limitations are expected in GNSS systems as a result of the ionosphere (except for ionosphere storms).



As may be noted, CAR/SAM, AFI, MID and part of APAC are clearly located in equatorial regions. Consequently, ionosphere issues related to the GNSS (ABAS, GBAS, and SBAS) must be addressed with special caution and rigour. For this reason, and also because of the high cost of SBAS systems, it is highly advisable to have a clear and scalable strategy in place to mitigate existing risks, while obtaining maximum benefits and proposing solutions suited to each region, as has been done in SACCSA for the CAR/SAM Regions.

Two important SBAS-related aspects converge in most of these equatorial regions: first, SBAS solutions in these regions are more complex due to the ionosphere, although, on the other hand, an SBAS augmentation solution would have a very positive cost-benefit ratio due to operational advantages and increased security given the possibility of implementing solutions with vertical guidance with no need to invest in local infrastructure in large ground areas. The following figure provides an overview of the level of security in relation to the percentage of accidents per region. (Figure provided by Boeing – 1997-2006 data.)



Suggested action

The States are invited to:

- take note of the information contained in this working paper.
- identify the technical and operational advantages each State would derive from the SBAS.