INTERNATIONAL CIVIL AVIATION ORGANIZATION

AFI PLANNING AND IMPLEMENTATION REGIONAL GROUP (APIRG)
COMMUNICATIONS, NAVIGATION AND SURVEILLANCE SUB-GROUP
SECOND MEETING
(CNS/SG/2)

(Dakar, Senegal 22 – 25 May 2007)

Agenda Item 5: Aeronautical Radio Navigation Service (ARNS)

Implementation of a GNSS satellite based augmentation system in the AFI Region

(Presented by the Secretariat)

SUMMARY

This paper addresses GNSS issues discussed at the Fifteenth Meeting of AFI Planning and Implementation Group (APIRG), particularly in respect of SBAS implementation in the AFI Rgion. Action by the CNS Sub-group is at paragraph 3.

REFERENCES

Doc 9828, *Report on the 11th Air Navigation Conference* (2003)
Annex 10, Volume I
*Reports on 11th, 12th, 13rd, 14th and 15th meetings of APIRG
Doc 9849, *GNSS Manual*

This paper is related to Strategic Objective D of ICAO.

*Main references

1. INTRODUCTION

On 2 May 2006, the ANC Working Group on Regional Plans (AN-WG/RPL) reviewed the report of the fifteenth meeting of the Africa-indian Ocean (AFI) Planning and Implementation Regional Group (APIRG/15), held in Nairobi, Kenya, from 26 to 30 September 2005. With regard to GNSS implementation matters discussed under Agenda Item 4.2, the AN-WG/RPL noted the opposition of the International Air Transport Association (IATA) to the implementation of a satellite-based augmentation system (SBAS) in the AFI region, known as the Inter-regional SBAS over AFI (ISA), and the lack of consensus among States. The AN-WG/RPL instructed the Secretariat to prepare documentation on this subject. On 31 May 2006 (172-7), the Commission noted the APRIG/15 report and the report of the AN-WG/RPL thereon (AN-WP/8136). Documentation prepared by the Secretariat was reviewed by the Commission during its 173rd Session.

2. DISCUSSION

2.1 Background

SBAS

2.1.1 An SBAS is a wide coverage GNSS augmentation system in which the user receives augmentation information from a satellite-based transmitter. The augmentation information is used to enhance the quality and availability of the GNSS service provided by the core GNSS constellations (currently GPS and GLONASS). A typical SBAS can support en-route, terminal and approach operations, including, in appropriate configurations, approach procedures with vertical guidance (APV).

2.1.2 In addition to the satellite-based transmitter and to the aircraft receivers, the SBAS architecture includes a network of ground stations that monitor satellite signals; master stations that collect and process the monitoring data and generate augmentation messages; and uplink stations that send the augmentation messages to the satellite for broadcasting to users.

2.1.3 Current and planned implementations of SBAS include the Wide Area Augmentation System (WAAS), the European Geostationary Navigation Overlay System (EGNOS), the Multi-functional Transport Satellite (MTSAT) Satellite-based Augmentation System (MSAS) and the GPS and GEO Augmented Navigation (GAGAN) system.

2.1.4 Additional information on SBAS can be found in Annex 10, Volume I, Attachment D, 6, and in the GNSS Manual (Doc 9849).

SBAS developments in AFI and the ISA

2.1.5 Since the entire African continent lies within the coverage area of the EGNOS satellites, it is possible to extend EGNOS to provide SBAS services in Africa by deploying the required ground infrastructure. The ISA system concept discussed at APIRG/15 is based on an extension of EGNOS to enable provision of SBAS services over the sub-Saharan Africa[1]. Such an extension has been under consideration by APIRG for some time.

2.1.6 APIRG/11 (1998) agreed to the deployment in the AFI Region of an EGNOS AFI Satellite Test Bed (ASTB) to conduct SBAS operational trials and demonstrations. Related activities continued over the following years, with the implementation of three EGNOS test beds using ten reference and integrity monitoring stations (RIMS) in Central, Southern and Eastern Africa, and culminating in flight trials conducted by an ASECNA test aircraft in June 2005 from Senegal to Kenya using the EGNOS signal continuously and operating a series of successful APV-I landings. In its final configurations, the ASTB included ten monitoring stations across Africa and associated communication network linking them to the central facilities of the EGNOS System Test Bed (ESTB). The ASTB ceased operations at the end of June 2006.

2.1.7 In parallel with trial and demonstration activities, APIRG pursued the development of an AFI GNSS strategy. A three-phase strategy was initially endorsed by APIRG/12 (1999), and updated by APIRG/13 (2001). Phases I and II of the strategy respectively addressed ASTB implementation and gradual deployment of SBAS infrastructure (in addition to general introduction of GPS-based en-route/NPA operations). APIRG/14 (2003) Conclusion 14/46 called for the implementation of an SBAS operational system as an extension of EGNOS, and included the

[1] In North Africa, EGNOS-related activities include the Euro-Mediterranean Satellite Navigation Project, a training and demonstration project conducted in the framework of the European Union's Euro-Mediterrenean Partnership MEDA programme, which will also address extension of EGNOS services in the area.

implementation of an SBAS operational systems in the work programme of its GNSS Implementation Task Force (GNSS/ITF).

2.1.8 APIRG/15 discussed ISA implementation in light of GNSS/ITF progress, pre-operational experience gained through the ASTB and the technical and cost-benefit information made available to the meeting. A proposed institutional framework for the ISA was endorsed by the meeting (Conclusion 15/18), whereby three sub-regional ISA service providers would be established. Each subregional ISA provider would be appointed and supervised by a management board composed of the concerned States/air navigation service providers and users, and an AFI-wide ISA Supervisory Board would coordinate with the three subregional boards. Funding options were also discussed, and the need for a meeting of AFI ATS providers identified as potential investors in the ISA was recognized, in order to plan the way forward with ISA implementation. A significant issue that emerged in the meeting, however, was the firm opposition by IATA to the implementation of SBAS in the AFI region.

2.1.9 A meeting of potential ISA investors was held in Cairo in February 2006. The European Space Agency (ESA) presented the new concept of Regional Extension Module (REM) as the basic component of the ISA architecture, in support of the sub-regional ISA service provider concept endorsed by APIRG/15. Three REMs would be required to provide service to the whole AFI region. The infrastructure for each REM could be developed and managed independently from the other REMs, and would include a number of monitoring stations (up to 15), a master control center (MCC), performance assessment and checkout facility (PACF) and network concentrator. Each REM would interface with the central EGNOS control facilities located in Europe. Continued interest in ISA implementation was expressed by participants, as were concerns with system costs, timescales and evolution.

2.1.10 Subsequent to the Cairo meeting, activity continued with a view establishing road maps for implementation and funding of the ISA at the sub-regional level, with the participation of relevant regional economic organizations.

2.2 ANALYSIS

General considerations

2.2.1 SBAS implementation has a central role in the ICAO strategy for transition to satellite-based air navigation. This is reflected in Recommendation 6/1 of the 11th Air Navigation Conference (2003), which urges States and airspace users to take note the of available and upcoming SBAS services and take the necessary steps towards installation and certification of SBAS-capable avionics. Major infrastructure investments have been committed to put in place near-global SBAS satellite coverage in support of international civil aviation (Section 2.1.3 refers), and it is incumbent on the aviation community to make the most efficient use possible of the available and planned SBAS infrastructure.

2.2.2 Introduction of SBAS services in the AFI region should be viewed in this context. While the main driver of the EGNOS programme is the provision of SBAS services in Europe, the coverage area of the EGNOS satellites extends to the AFI region, and an opportunity exists to make use of the EGNOS infrastructure to provide SBAS services in the AFI region as well. The work conducted within APIRG and supported by ASTB implementation has been driven by a commitment to explore this opportunity and turn it into an operational reality.

2.2.3 The planning process associated with the introduction of GNSS services is described in the ICAO *GNSS Manual* (Doc 9849). As discussed there (Section 1.5.2), when considering the introduction of a GNSS augmentation system, an analysis should be conducted to consider all the costs and the benefits from the perspectives of the service provider and of the users. In the course of

the activities related to the introduction of EGNOS services ot the AFI region, cost-benefits considerations have been explored at various levels, and a number of studies have been developed in several fora, including APIRG. The following sections are based on information gathered from those studies.

Benefits

2.2.4 The potential benefits associated with the ISA fall into three main categories: safety improvements; operational efficiency improvements; and reduced infrastructure costs.

2.2.5 Most of the safety improvements would stem from the introduction of SBAS-based APV procedures, as described in Phase 2 of the AFI GNSS strategy endorsed by APIRG. APV procedures constitute in general a safety improvement over NPA procedures, due to the availability of vertical guidance, and are recognised as an effective means of preventing CFIT. In particular, SBAS-based APV procedures can provide improved integrity and reduced minima if compared with other APV procedures (APV Baro-VNAV). Operational efficiency improvements would derive mainly from the avoidance of weather-related diversions. According to one study which took into account statistics of AFI weather conditions, between 2 and 3.5% of the conditions that would be unsuitable for NPA operations, and therefore lead to a diversion, would not result in a diversion if SBAS-based APV operations were implemented. Over a sufficiently long period, the costs associated with the conventional navigation infrastructure could also be reduced, if full SBAS aircraft equipage is achieved.

2.2.6 Attempts to quantify these benefits have been performed. One recent study arrived at a total of €336M over 15 years (€149M net present value), taking into account costs of hull loss, statistical value of life, average disruption costs per flight associated with delay, diversion or cancellation, number and operational state of AFI navaids, and their operating and renewal costs. The study assumed that 10% of the fleet would upgrade to SBAS avionics every year, yielding 100% aircraft equipage in ten years. Accordingly, the yearly amount of benefits achieved was assumed to grow in a near-linear fashion from 0 to € 40M/year. The study did not take into account the availability of APV procedures at all airports where APV operations were to be implemented.

Costs

2.2.7 Only rough cost estimates have been made available so far in the framework of the ISA programme. Recent estimates are for an infrastructure architecture based on the REM concept described in 2.2.4. Capital investment for each of the three REMs envisaged is €10-15M, with yearly operating costs of €3-5M. Similar figures (ranging from €30M to €50M for the total system infrastructure and 10) have appeared in other cost-benefit studies. The relative lack of detail in the estimates has been quoted as a cause of concern by potential investors. The uncertainty in the cost to the air navigation service provider also translates to uncertainty on the potential impact on user charges.

2.2.8 One major cost element that has not been discussed in quantitative terms in recent studies is that of the aircraft SBAS receivers. Such receivers are a necessary condition to enable the fruition of the potential benefits discussed in 3.5. Given the likely magnitude of this cost element, any cost-benefit analysis that does not address it cannot be considered complete. Other cost elements that still need to be assessed include cost of APV procedure development, training of pilots, ATC personnel and REM operators.

Other issues

2.2.9 In addition to the cost-benefit considerations outlined above, other aspects that need to be considered include technical considerations, institutional arrangements and user consensus issues.

2.2.10 One technical issue of major relevance to ISA implementation is the impact of the behavior of the ionosphere on GNSS performance in low-latitude areas. In general, ionosphere impact varies with time and location. Factors involved include the 11-year solar cycle, the season of the year, time of day and geomagnetic latitude. Within low-latitude regions, including most of the African continent, ionospheric effects are the most severe. As a result, while availability of NPA service is not significantly affected, the actual achievable availabilities of APV service in equatorial regions (and hence the full fruition of the associated benefits) are uncertain and currently under assessment.

2.2.11 In particular with regard to the ISA, preliminary results under simulated nominal and worst ionospheric conditions are expected to be available by the end of 2006. In this connection it should also be noted that ionosphere studies have been conducted in the CAR/SAM regions (which present ionosphere conditions that are similar to the AFI region). The results of those studies were presented to the GREPECAS/13 meeting and were among the elements that led the meeting to conclude that it was technically and operational impracticable to extend existing SBAS systems to the CAR/SAM regions.

2.2.12 Another issue is related to the fact that, as discussed in 2.2.4, full ISA implementation would be reliant on an complex ground system infrastructure, involving 30-45 monitoring stations, three regional control centers, and the associated communication links. The development of such an infrastructure on a continental basis represents a major technical and project management challenge. Also, many of the practical issues identified with the maintenance and operation of the current navaids infrastructure in the region would apply to the ISA infrastructure as well.

2.2.13 With regard to operational use of the ISA infrastructure, it should be noted that introduction of SBAS-based APV operations at a number of airports sufficient to generate the projected benefits would require an extensive development of APV procedures. Experience with development of GNSS-based approach procedures in the region has shown that such a development could represent a sizeable and demanding project in its own right.

2.2.14 With regard to institutional considerations, the joint development and operation of a single AFI-wide navigation system (the ISA) as an operational extension of a EUR-based navigation system (EGNOS) can be expected to present some challenges. The institutional structure model proposed in Conclusion 15/18 represent a reasonable approach to deal with those challenges. However, the inherent complexity of the institutional scenario remains considerable, and may hamper transparency and efficiency.

2.2.15 Issues associated with user consensus have emerged recently, notably with IATA's statement of firm opposition to the ISA that was recorded at APIRG/15 (APIRG/15 report 4.2.24). The basis for IATA's specific opposition to the ISA was provided by two main lines of argument, as expanded upon in correspondence with the ICAO Secretariat. The first challenged the actual safety benefits of SBAS-supported APV, both in absolute terms (arguing that CFIT was not a major problem in Africa) and in relative terms (comparing it with APV Baro-VNAV-type procedures). The second invoked the cost of SBAS aircraft equipage as a factor preventing African airlines from equipping. In addition to the specific opposition to the ISA, IATA has also stated a general position of opposition to SBAS [get latest from IATA].

2.2.16 While the IATA opposition to the ISA may not represent the views of all prospective users, it does reflect a coordinated position in the airline industry, and as such needs to be fully

addressed to find a way forward. The specific lines of argument underlying the IATA position can be challenged, but the continuation of a debate at this level is unlikely to be conclusive at this stage.

2.3 AVAILABLE OPTIONS

2.3.1 Extensive preparation work for SBAS implementation in AFI has been conducted for several years within the relevant ICAO groups with the assistance of EGNOS programme expertise and resources. In addition to studies and planning activities, this work has included the development of the ASTB to demonstrate potential ISA applications through flight trials.

2.3.2 Preliminary work included cost-benefit studies and a number of potential benefits have been identified; however, such benefits depend in a critical manner on the level of aircraft equipage and procedure introduction that will be achieved. With regard to assessment of the costs, only rough estimates are currently available for the cost of the ground infrastructure required, whereas the cost of aircraft equipment has not been addressed, even though it is likely to represent a major portion of the total costs.

2.3.3 A number of issues exist that contribute to raise the level of uncertainty of the overall cost-benefit assessment. While some may be managed through further study and preparation work, the issue of user consensus (which directly affects the prospects for aircraft equipage and hence the overall benefits of the system) needs to be examined in coordination with the users themselves. As suggested in Doc 9849 (1.5.2), if the cost-benefit analysis conducted as a part of the introduction of a GNSS augmentation system is not conclusive, or is not positive for one of the participants, service providers, regulatory authorities and users should examine the various available options to find the best solution.

2.3.4 Available options include:

a) Delaying consideration of the ISA until further cost-benefit analysis in coordination with users demonstrates a conclusive need. This option would have the additional advantage that it would benefit from operational experience with the EGNOS system and associated aircraft equipment and procedures that would be gained in the EUR region (the primary service area of EGNOS). This option would result in a prolongation of the current Phase I of the AFI GNSS strategy, which allows the use of Basic GNSS (GPS augmented with ABAS) from en-route down to NPA. The prolongation would be consistent with the fact that Phase I has effectively not been completed uniformly throughout the region (as of February 2006, en-route use of Basic GNSS was not approved in a majority of AFI States, and NPA procedures and/or related regulatory texts had not yet been published);

b) Introducing the ISA with a reduced infrastructure that would enhance en-route/NPA performance but would not enable APV. This option would enhance the availability of GNSS service compared to the current situation, as the required level of integrity would be available for a greater percentage of time. It would also reduce considerably the ground infrastructure costs, compared to full ISA implementation, as only a small number of monitoring stations would be required, while at the same time it could represent a first step towards full implementation. However, the actual benefits generated by this option would be significantly smaller compared to a full infrastructure, and would still be conditional on the level of aircraft equipage with SBAS receivers, and subject to the related uncertainties;

c) Proceeding with full-scale introduction of the ISA, consistently with Phase II of the AFI GNSS strategy (2006 – 2011), which envisages availability of SBAS APV everywhere in the region.

2.4 RECOMMENDATION BY THE AIR NAVIGATION COMMISSION

2.4.1 As mentioned above, documentation prepared by the Secretariat was reviewed by the Air Navigation Commission during its 173rd Session, taking into account the results of several studies addressing cost-benefit considerations in connection with SBAS implementation in the AFI Region. Technical aspects, institutional arrangements and user consensus issues were also considered.

2.4.2 With regard to cost-benefit considerations, a number of potential benefits have been identified in the studies; however, such benefits depend in a critical manner on the level of aircraft equipage and procedure development. Only rough estimates are currently available for the cost of the ground infrastructure required, whereas the cost of aircraft equipment has not been addressed in most studies. Therefore, the available information is insufficient to support a conclusive cost-benefit analysis.

2.4.3 A number of issues exist that raise the level of uncertainty of the overall cost-benefit assessment. They include the impact of the ionosphere on GNSS performance in low-latitude areas, the complexity of the ground infrastructure and of the institutional arrangements required and the lack of user consensus.

2.4.4 Based on the above considerations and in light of the Commission's discussion of this topic, the Commission is of the opinion that option a) in paragraph 2.3.4 above should be considered as the recommended approach for the AFI Region.

2.4.5 Furthermore the issue of SBAS implementation was seen by the Commission as relevant to the meeting that should be convened prior to the 36th Session of the Assembly to discuss a Regional Implementation Plan for the AFI Region, in particular safety-related issues in the region.

3. ACTION BY THE CNS SUB-GROUP

3.1 The CNS Sub-group is invited to :

a) note the information provided in this working paper ;
b) note the available options for the implementation of a satellite based system (SBAS) in the AFI Region as described in paragraph 2.3.4 here above ;
c) endorse the Air Navigation Commission's recommended approach as indicated in paragraph 2.3.4 a) here above ; and
d) take it into consideration when discussing AFI strategy for the introduction of GNSS.

- END -