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English and French only[1]

ELEVENTH AIR NAVIGATION CONFERENCE

Montreal, 22 September to 3 October 2003

Agenda Item 6 : Aeronautical navigation issues

FIRST SATELLITE BASED AUGMENTATION SYSTEM (SBAS) IN AFRICA

(Presented by ASECNA)

SUMMARY

Recognizing the strategic importance of satellite navigation, its potential applications and the current GNSS systems deficiencies, the AFI Region decided to develop its own GNSS implementation strategy in a three-step approach through the implementation of a SBAS-type system called EGNOS to cover the short and medium needs and through a full fledge satellite navigation constellations like Galileo, GPS and Glonass, for the long term.

The current paper is intended to emphasize the following points:

1) the experience ASECNA has gained in the use of the GNSS through APV1 (approach with vertical guidance) trials within western and central areas in Africa (First step of AFI GNSS strategy);

2) the necessary cooperative step needed for GNSS global and seamless implementation; and

3) a concrete proposal to facilitate the implementation and operational use of GNSS and its relevant elements.

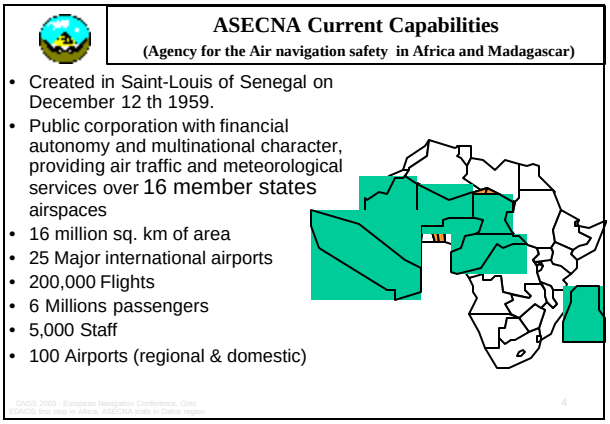
Action by the conference is in paragraph 8.

[1] French version provided by ASECNA.

(8 pages)

1. INTRODUCTION

1.1 ASECNA current capabilities



ASECNA's current facilities are mainly ground-based ones and it essentially use classical technologies for services such as:
Communications: quickly evolving to VHF with remote VSAT; X25 data network
Navigation: Ground-based (ILS, VOR, DME, NDB,.)
Surveillance: Pilot positional reports, ADB/C and secondary radars with on-going implementation

1.1.1 For the future, the Agency for Air Navigation Safety in Africa and Madagascar (ASECNA) is willing to take most advantages of new satellite based technologies dealing with ICAO's communications, navigation, and surveillance/air traffic management (CNS/ATM) concept.

1.1.2 On the ground side, ASECNA facilities would be based on:

a) communications: additional very small aperture terminal (VSAT), very high frequency (VHF) voice/data Link, controller-pilot data link communications (CPDLC), aeronautical telecommunication network (ATN);

b) navigation: Global Positioning System (GPS), European Geostationary Navigation Overlay Service (EGNOS), ground-based augmentation system (GBAS) (few expected after 2012);

c) surveillance: automatic dependent surveillance — broadcast (ADS-B) and ADS-C; and

d) air traffic management (ATM): Automation related to communications, navigation, and surveillance (CNS) modernization.

1.1.3 Avionics (by airlines) should therefore include:

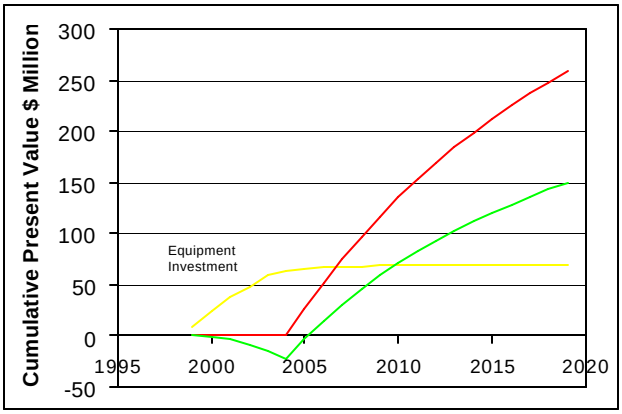
a) communications avionics: VHF digital link/time division multiple access (VDL/TDMA), controller-pilot data link communications (CPDLC);

b) navigation avionics: EGNOS/GBAS; and

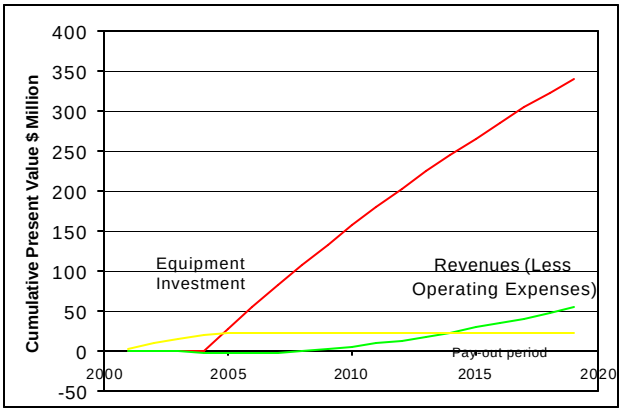
c) surveillance avionics: ADS-B and C

1.2 ASECNA business case

1.2.1 An ASECNA Business Case assessing Capital Investment Plan (2000 -2006) for CNS/ATM Modernization was made in 1998 with ICAO assistance and presented at the World-Wide CNS/ATM Systems Implementation Conference of RIO in May, 1998. The two pictures below give an idea of both ASECNA and airlines cash flow profiles resulting from CNS/ATM implementation.



ASECNA CASH-FLOW PROFILE



AIRLINE CASH-FLOW PROFILE

This study has demonstrated the benefits that can be gained from the global navigation satellite system (GNSS) implementation, in terms of safety and performances, while reducing the costs of the ground-based navaids infrastructure, often difficult to install and maintain.

2. GNSS AFI STRATEGY

2.1 Methodology

2.1.1 Dealing with GNSS strategy, the point to consider was to identify, for each GNSS application and modes of operation, what would be the performance requirements and to identify what augmentations, if any, are required to meet such requirements, differentiating between those of a local, regional, and multi-regional nature. This should make it possible to take informed decisions on those desirable, affordable, and cost-effective.

2.1.2 The methodology used to define AFI GNSS Strategy therefore led to:

a) review existing navaids and telecommunications facilities;

b) analyse current and forecast traffic based on the fleet types;

c) define operational requirements and conduct statistical analysis of ceiling and visibility for the capital city airports identification of operational needs for different user classes;

d) compromise between different GNSS and telecommunications architectures;

e) assess the total cycle costs of each system option, including ground, space, and on-board elements and establish the cost-benefits case for air traffic services (ATS) service providers; and

f) discuss on institutional issues involved with each scenario and system option and define steps for the implementation of GNSS system in Africa, establishing therefore AFI GNSS Strategy.

2.2 **Considered scenario for AFI Region**

2.2.1 To address the various scenarios, the three categories of augmentation systems have been considered: aircraft-based augmentation system (ABAS), satellite-based augmentation system (SBAS) (so-called wide area differential) and ground-based augmentation system (GBAS) (so-called local area differential).

2.2.2 Regarding SBAS, the proposed architecture relies on the assets of EGNOS, the SBAS system developed by the European community. The AFI region is well covered by EGNOS geostationary satellites (IOR, AORE ...). Where it was found cost beneficial for the AFI region, re-use of part of the EGNOS system was considered in order to offer the required service while avoiding unnecessary expenses.

2.2.3 Four architecture scenarios were defined and evaluated by simulation:

A: Scenarios without ground infrastructure:

— A1: GPS only receiver on board

— A2: GPS with ranging from EGNOS

B: Scenarios with ground infrastructure:

— B1: SBAS for APV-1 and GBAS for CAT-I

— B2: SBAS for APV-1 and CAT-I in some areas and GBAS elsewhere where needed

2.2.4 Discussions through a study group led to consider, in the short- and medium- term, scenario B1 as the one to be preferred in regard to performances achieved and required equipment:

a) 13 - 15 reference stations required for standard performances, (higher number to take into account failure modes);

b) horizontal accuracy: 16 m, HAL: 40 m;

c) vertical accuracy: 20 m, VAL: 50 m;

d) availability: >99%, compliant; and

e) continuity: $< 10^{-8}$, compliant

3. ICAO GNSS AFI STRATEGY: 3 PHASES

3.1 ICAO GNSS AFI Strategy adopted by APIRG includes three phases summarized as follows:

a) **Phase I (short term), up to 2004:** Additional ranging and health information on GPS:

1) this phase will allow the use of GNSS for en-route, and for NPA. Existing ground infrastructure remains intact;

2) this phase will end with EGNOS validation in the AFI Region;

b) **Phase II (medium term) 2005-2011:** APV-I -I, 20m vertical accuracy everywhere in the region; and

c) **Phase III (long term) 2012 onwards:**

1) the study group assumed that at least two constellations of navigation satellites will be available and could provide from en-route up to CAT 1 GNSS sole means operations; and

2) CAT I by SBAS or GBAS will be available in those locations where analysis of historical meteorological (MET) data or traffic characteristics justifies the requirement.

4. AFI EGNOS TEST BED (PHASE 1 OF THE GNSS AFI STRATEGY)

4.1 Phase I of the GNSS AFI strategy emphasized the need for the implementation of an SBAS test-bed in order to validate the performances and behaviour of the future system. Three areas were selected: area A for Central Africa, B for South Africa and C for eastern Africa. ASECNA proposed to ensure the implementation of the test bed in area A and negotiated with the European Commission and Space Agency the loan of the four stations. The French Civil Aviation for the avionics and data processing provided adequate technical support.

4.2 Main objectives of the project

a) to verify the navigation performances over selected areas and airports of Western and Central Africa;

b) to validate the simulation model outside Europe;

c) to evaluate some critical issues (telecommunication network, receivers ...);

d) to analyse ionospheric impacts;

e) to evaluate APV1 procedure design, constraints and operations;

f) to sensitize potential services providers and users;

g) to sensitize and train ASECNA's personnel about this new technology; and

h) to develop expertise in the view of the implementation of the AFI test bed.

4.3 The dynamic trials are to demonstrate APV1 benefits such as:

a) EGNOS Approach on runway axis;

b) control of the vertical position thanks to the EGNOS signal and added descent fixes;

c) no more flat step before the miss approach point; and

d) reduced controlled flight into terrain (CFIT) risk.

4.4 **DAKAR trials**

4.4.1 Due to 95 per cent availability of native EGNOS test bed augmentations (horizontal and vertical NSE, VPL) in the Dakar Region after the installation near Dakar airport of an EGNOS reference mobile station (RIMS) in July 2002 , it was decided to proceed to initial trials in Dakar, through an ASECNA, European Space Agency (ESA), EC, the European Organisation for the Safety of Air Navigation (EUROCONTROL), French DGAC and AENA partnership with a no funds exchange principle. Trials in Dakar included:

a) static and dynamic trials to evaluate the performance of the EGNOS signal over Western Africa; and

b) flight demo at different airports, using the ASECNA ATR42 calibration aircraft equipped with EGNOS capabilities.

4.4.2 Results of the Dakar trials are the followings:

a) twelve flights in three days with more than thirty APV1 approaches with instrument landing system (ILS) comparison;

b) more than seventy participants including pilots and ICAO, African Civil Aviation Authorities, French DGAC, ESA and EUROCONTROL representatives;

c) twenty ASECNA staff trained on GNSS technology and GPS processing;

d) quality guidance like ILS (accuracy performances, pilot point of view: pilots noticed no significant difference with ILS signals, when available). Demonstration of possibility approaches on a non-equipped QFU with ground navaids infrastructure;

e) in Dakar, APV 2 accuracy requirements were met during most of the approaches, in spite of a very unfavourable test bed configuration, resulting in degraded availability performance;

f) poor constellation led to a minimal number of monitored satellites;

g) important ionospheric effects, detailed analyses are on-going; and

h) all results show no miss integrity.

4.5 Area A AFI EGNOS test bed

4.5.1 The implementation of the EGNOS test in Area A, located around the equator and with important ionospheric perturbations, is paramount to assert the performance of such a system.

4.5.2 Build upon a network of four ranging and integrity monitoring stations (RIMS) installed by ASECNA in April 2003 at Lomé (Togo), N'Djaména (Chad), Brazzaville (Congo) and Douala (Cameroon) and using the Agency Satellite communication network to link all the stations to the ESTB European Processing Facility in Norway, it allows to get an APV1 service level on the following States:Togo, Benin, Nigeria, Cameroon, Equatorial Guinea and Gabon.

4.5.3 An important trials and demonstration campaign was carried out on some airports of the above States (Except Benin) and static trials (acquisition of raw data) are still on going.

4.5.4 Test bed in Area A will contribute to evaluation of EGNOS Signal in Space in equatorial regions and preparation to Areas B (South Africa) and C (Eastern Africa) test bed trials.

4.6 Lessons learned

4.6.1 Preliminary results show EGNOS may satisfy AFI navigation requirements in phases I and II of GNSS AFI Strategy.

4.6.2 Trials and demonstrations in AFI region were possible with close cooperation of the European Space Agency (ESA) and the European Commission.

4.6.3 Lots of works to be done to prepare these phases and also phase III, including mainly:

a) analyse of the AFI test-beds results;

b) finalize the SBAS architecture required for the AFI Region AFI and the adaptation of the European system;

c) prepare the funding (see note);

d) study the institutional aspects;

e) invite the potentials users to equip the aircraft with GNSS avionic; and

f) speed up the standardization of APV1 procedures by ICAO.

4.6.4 According to some estimate, the worldwide market for satellite navigation could be worth as much as 50.000 millions Euros by year 2005, so the cost of supplementary RIMS for SBAS extensions in the word is not significant.

Note.— The cost of EGNOS extension implementation in Africa is ranging from 15 to 20 millions dollars for Test bed with 16 RIMS for pre-operational system; (communications infrastructure, maintenance and communications fees and avionic costs are not included)

5. CONCLUSION

5.1 The global ATM operational concept (GATMOC) acknowledges the need of a global, seamless, safe and efficient system for air navigation. The GNSS, with its various augmentations (wide area augmentation system (WAAS) and LAAS from the United States, EGNOS from Europe and multifunctional transport satellite (MTSAT)/multifunctional transport satellite-based augmentation system (MSAS) from Japan, GAGAN from India,) is the most suitable system to meet a large part of such need. This is especially relevant to AFI Region where the implementation costs for traditional air navigation means are quite prohibitive.

5.2 Trials have shown clear benefits from the use of GNSS in the AFI Region. They have demonstrated that it is quite possible to install and operate GNSS augmentations in Africa, following the example of other regions in the world. This ensures that the seamless objective of ATMOC can be met in the AFI Region.

6. ACTION BY THE CONFERENCE

6.1 The conference is invited to:

a) note ASECNA's contribution to the GNSS implementation in the AFI region and the valuable experience gained in this field;

b) recommend that, as a contribution to a seamless global ATM, GNSS satellite-based augmentation systems (SBAS) providers development programmes should include the deployment and pre-finance of the infrastructure necessitated by APV1 operations in neighbouring countries and regions within the system service and coverage area;

c) recommend that approach with vertical guidance, type 1 (APV1) using GNSS be considered as an ICAO formal requirement worldwide;

d) recommend that States establish the necessary regulatory framework to govern the use of GNSS;

e) invite the airlines and other GNSS potential users to equip their aircraft with relevant avionics; and

f) call upon air navigation service providers and potential users for them to participate in SBAS pre-operational and operational implementation activities.

— END —