International Civil Aviation Organization

First Meeting of the APIRG Communications, Navigation and Surveillance Sub-group (CNS/SG/2)
(Dakar, 22-25 May 2007)

Agenda Item 5: **Follow Up on APIRG Conclusion 15/19 –AFI Interregional SBAS Potential Investors Workshop (Cairo, Egypt, 14-15 February 2006)**

(Presented by the Secretariat)

SUMMARY

This paper gives account of events during and after the Cairo Investors Workshop.

.Ref :-
Report of the investors workshop
Report on Implementation Of SBAS in AFI by ICAO Council
APIRG/15 Report

1. Introduction:

1.1 In pursue of APIRG Conclusion 15/19 AFI Interregional SBAS Potential Investor Workshop was held in Cairo, Egypt 14-15 February 2006. The main objective of the workshop is to identify potential investors for the AFI SBAS system.

2. Discussion

2.1 The Workshop was well attended by AFI States and Investors from Europe and Africa (see the attached report).If you will recall at APIRG/15 Europe Space Agency (ESA) informed the meeting that it has contracted an industrial group to conduct detailed Inter-regional SBAS over AFI (ISA) feasibility studies including ionosphere, communications network, central processing facility extension, ISA architecture and cost assessment. However, at the time of the workshop the report was not presented. The cost benefit analysis that was presented was without the airborne component. in particular, the cost of retrofitting the Aircrafts in service now. In the absence of the report there was not much that could be done. However, ESA promised to make the report available by June 2006. Sates were urged to foster the identified Institutional Structure for the AFI Interregional SBAS.

2.2 ICAO Council, during the review of APIRG/15 report decided to have a special session on implementation of SBAS in AFI and to issue guide lines on the implementation.. The council session was held on October 2006 comprehensive cost benefit analysis was submitted to ICAO Headquarters by ESA.(see Appendix B) The outcome of the Council session will be discussed at this meeting. However States must endeavor to implement the phase one of the AFI GNSS strategy.

3. Action to be taken by the meeting.

3.1 The meeting is invited to:

a) take note of the above information;

b) urge States to continue to assign high priority to the implementation of the phase one of AFI GNSS strategy and inform the regional office of any difficulties encounter.

c) request ESA to submit the comprehensive report on the AFI TESTBED

ISA Potential Investors Workshop Report

ISA Potential Investors Workshop
Cairo, 14-15 February 2006

The workshop attracted considerable interest from AFI ATS providers and industry, with 45 participants attending (see attached list of participants). On both days the workshop overran the foreseen time, primarily to due the numerous questions and lively discussions that followed the presentations.

This report is not a verbatim summary of workshop but rather a brief synopsis of the key points touched upon during the two days. See attached Agenda for the complete list of presentations.

1. A presentation by the GEMCO Director on the extension of the European EGNOS system to the MEDA region, and more specifically to North Africa, made it clear that ISA (Inter-regional SBAS for AFI) only refers to the implementation of SBAS in sub-Saharan Africa.

2. For the first time, ESA presented the concept of Regional Extension Module (REM) as part of their ISA Extension Preliminary Design. A typical REM consists of a regional control centre and a number of RIMS (e.g. 10, but this number is flexible). This means that sub-Saharan Africa could be covered by by 1-3 REMs. The REM concept offers optimal technical and programmatic flexibility.

   Preliminary results from the ESA ISA Extension Preliminary Design Review study, indicates that 25 RIMS are sufficient to provide APV capabilities over Africa, but that an additional number might be needed to overcome the ionosphere corrections problems over the equatorial region. An estimated additional 5 RIMS for Central Africa has been suggested – a final assessment will be made in ESA's ISA Extension Preliminary Design Review study to be completed by end April 2006.

3. ESA presented cost element categories, consisting of EGNOS system upgrade costs and ISA development work, as well as the costs per REM system. Clearly the overall costs depends on AFI's choice of capability options and the final number of REMs and RIMSs.

   However, to give the AFI sub-regions some idea of the costs that they may face, ball-park figures for the various cost elements were mentioned (these were not included in the viewgraphs) based on EGNOS experience in Europe:
   CAPEX - € 1M per RIMS for procurement, installation and qualification
   - € 5M for a REM control centre and network integration

   OPEX - around 10 staff per REM including 2-3 operators and 7-10 engineers (staff costs will depend on local staff rates)
   - communication costs of € 50-80k per RIMS line per year
   - site services (including costs of hostings of sites) of € 20k per site per year
   - maintenance costs of 5-10% of equipment procurement

   It was also pointed out that there is likely to be a 2-3 year delay between the first RIMS deployment and full operation of the REM. This means that provision will need to be made in each sub-regional business case for a delay between the up-front investment and the point at which certified services will be provided.

Regarding RIMs hosting, it requires 24 hour availability of qualified, maintenance staff. This together with the requirements for security and communication links is why the vast majority are hosted in the vicinity of airports and control towers. Here slightly different cost figures for the RIMs were presented:

- € 1M for equipment procurement, site engineering, site deployment, network connection and site integrations
- € 500k to build the infrastructure, install services and for support on site

4. ICAO presented a overview of the APIRG GNSS three-phase strategy that was agreed in 1999. This first phase includes the implementation of a SBAS testbed, the second implementation of augmentation for APV-1, and the third the use of both GPS and Galileo constellations for sole-means of navigation. They presented the implementation progress across States for GNSS as primary means for en-route navigation, and the introduction of NPA procedures.

   It was noted that one of the conclusions of APIRG/14 (June 2003) was that a GNSS SBAS operational system be implemented in the AFI Region as an extension of the EGNOS. The following meeting, APIRG/15 (Sept 2005), further supported this and agreed the structure of three regional groups (West/Central, Southern and East Africa) for ISA implementation (as put forward by the GNSS Implementation Task Force).

5. A number of presenters pointed out that interfaces between EGNOS-Europe and the ISA REMs will need to be elaborated, in particular with regard to
   - Institutions
   - Management and technical development
   - Operations and services

6. Concerns were raised about the possibility that EGNOS will be replaced by Galileo. Giorgio Solari (GJU) made a statement to allay these concerns along the lines of:
   - EGNOS is intended to be operated by the Galileo concessionaire for the full 20-year duration of their contract, thus until 2025
   - With some minor modifications, the EGNOS RIMSs could be upgraded to monitor the Galileo SIS as well

   (see first viewgraph of the Workshop Conclusions)

7. From the presentation made by the EIB, an number of new aspects come to light:
   - An initiative to develop a EC/EIB trust fund for infrastructure projects in Afirca has just been signed.
   - EIB have a broad range of instruments that can be ulitised, including loans, quasi-equity, equity and guarantees.

8. ATNS, South Africa made a brief presentation on their investment in and operations of the VSAT network across SADC. This is currently being upgraded and in parallel they are implementing a VSAT network (NAFISAT) in East and North Africa. They illustrated their VSAT contractual model and cost recovery routes, and suggested that a similar

model could also be applied to ISA. A similar presentation was performed by ASECNA for their VSAT network.

9. Based on earlier ISA cost figures, they did a first cut estimate of what the additional charges to airlines might be for ISA services. This simple analysis gave a charge of €10-15 per flight. This early result would seem to indicate that the additional charge will only be a small percentage (~ 1%) of the current flight fees.

10. During the Tour de Table ATNS (RSA) and ASECNA stated their intent to implement ISA in their region.

    ATNS raised the following issues
    - They require further details on the final architecture and costs to themselves, and benefits and costs to their clients, the airlines
    - They need to get agreement from their clients to proceed with the investment
    - They have started their CAPEX planning for the next 5-10 years, and hence the timing for them is good

    ASECNA needs agreement from their 17 Member States to proceed. In principle, the Board have decided to implement SBAS and they have the intention of organising a forum in the region to better inform all MS. Decisions about investment would be then made in July 2006 at their Ministerial meeting. They also raised concerns about the lack of more detailed cost figures. They foresee that a definite plan for ISA will be outlined by Dec 2006.

    Kenya raised concerns about the final architecture in their region (final number of RIMSs) and about the lack of cost figures.

    Tanzania reiterated that they also need the agreement of their users. It wa mentioned that many SPs in East Africa do not have the resources to invest in ISA, and they requested further information on funding options what would be open to them. It was noted that there will be a transition period while traditional navaids will be operated together with ISA, and it was not clear how users would be chaged during this phase.

    Cameroon pointed out that ASECNA provides navigation services for them, but that each state has the responsibility of adhereing to regulation. They requested support to develop such regulation.

10. Regarding the way forward, it was noted that:
    - The results of the ESA ISA Extension Preliminary Design Review study will be available in April 2006
    - An institutional model needs to be launched, with the formation of a management board in each region. This needs to be driven by States in that region.

A number of suggestions were raised during a lengthy discussion on the way forward. These were collated and presented on a number of clarification and conclusion slides, and following review and revisions by the participants, these conclusions were adopted by the meeting. (See attached conclusion viewgraphs.) The main conclusions state:

- Participants reiterate their interest in the possible implementation of a SBAS in AFI (ISA) based on the REM concept presented by GJU/ESA
- Participants confirm that the REM concept as presented would allow meeting the objectives set by the AFI GNSS strategy
- Participants take note of the ongoing study on this REM concept conducted by ESA and request ESA to confirm the budgetary and technical information to be provided to the participants by end April 2006.
- Participants express their interest in the development by ESA of the EGNOS interface allowing to connect the AFI REM nodes and encourage the GJU and ESA to confirm the implementation scenario in the timeframe 2007 to 2008.
- Based on the above, participants agreed that:
  - Sub-regional groups as identified by APIRG 15 be promptly set up with the objective to elaborate road maps for the implementation including funding structure of ISA, with involvement of relevant regional economic organisations. Each sub-regional group should produce implementation scenarios by end June 2006.
  - An ISA steering group be created to coordinate and harmonise the work of three sub-regional groups and ensure liaison with MEDA and Middle East interface

Coordinators of the sub-regional groups were agreed (viz. ATNS for Southern Africa, ASECNA and Ghana for Central/West Africa and Keyna for East Africa). The TOR and short-term actions of the sub-groups are briefly outlined. Finally the composition of the AFI Steering Groups was proposed, which includes the sub-group coordinators, ACAC, AFCAC, GEMCO, GJU, Regional Economic Communities, users and ICAO as overall coordinator.

In summary, the concerns raised by participants mainly concerned

- System costs, timescales and evolution
- Charging policy during the transition from conventional radionavigation infrastructure to ISA
- Need to increase stakeholders' awareness of ISA benefits, in particular users and instituitions
- Need to increase public awareness of the complementary long term role of EGNOS and Galileo

Overall the workshop was successful as evidenced by the continued support for ISA implementation by the participants and the strong conclusions that were agreed by all.

ISA Potential Investors Workshop
(Cairo,14-15 February 2006)

LIST OF PARTICIPANTS

N	STATE/ORGANIZATION	NAME/DESIGNATION	ADDRESS	TELEPHONE/FAX	E-MAIL
1	**EGYPT** **Egyptian Civil Aviation Authority**	Mr. Nagy Saleh, Head of Air Navigation Central Administration	Ministry of Civil Aviation Complex, Cairo Airport Road, Cairo, Egypt	Tel: +20 2 266 3757 Fax: +20 2 266 5435	
2	**EGYPT** **Egyptian Civil Aviation Authority**	Mr. Mahmoud el Ashmawy, G.D. AT/RN (ECAA)	Ministry of Civil Aviation Complex, Cairo Airport Road, Cairo, Egypt	Tel: 202 2681347	
3	**EGYPT** **National Air Navigation Services Company (NANSC)**	Mr. Mohie ElDeen Ragheb	Egypt – Cairo Airport Cargo Village Road National Air Navigation Services Company (NANSC)	Tel: 202 2680716 FAx: 202 2680716	mohey.ragheb@nansceg.org
4	**EGYPT** **National Air Navigation Services Company (NANSC)**	Mr. Mohamed Atef Amar Manager of Following up the Regional Recomendiations	Egypt – Cairo Airport Cargo Village Road National Air Navigation Services Company (NANSC)	Tel: 202 2671056	atefammar954@hotmail.com
5	**EGYPT** **National Air Navigation Services Company (NANSC)**	Mr. Galal Mohamed Ibraheem	Egypt – Cairo Airport Cargo Village Road National Air Navigation Services Company (NANSC)	Tel: 202 2685279 Tel: 2012 7173348	galal.ibrahim@nansceg.org

N	STATE/ORGANIZATION	NAME/DESIGNATION	ADDRESS	TELEPHONE/FAX	E-MAIL
6	**B2LS Consulting**	Mr. Beethoven Tayel - Managing Partner			beethoven@b2lsconsulting.com
7	**TANZANIA** **Tanzania Civil Aviation Authority**	Mr. M.R. Alloo Director of Air Navigation Services	P. O. Box 2819 Dar es Salaam Tanzania	Tel : +255 22 212 4654 Fax : +255 22 2118905	malloo@tcaa.go.tz tcaa@tcaa.go.tz
8	**GEMCO**	Mr. Mohamed Elkady	Egypt – Cairo Airport Cargo Village Road National Air Navigation Services Company (NANSC)	Tel: +2010 6504438 Fax: +2022687849	Mohamed.elkady@nansceg.org
9	**GEMCO**	Mr. Maged Abu El-Ela Nofal	Egypt – Cairo Airport Cargo Village Road National Air Navigation Services Company (NANSC)	Tel: +20101596369 Fax: +202 2687849	Maged.nofal@nansceg.org
10	**European Investment Bank (EIB)**	Mrs. Catherine Collin ACP Department Portfolio Management & Policy Division	100, Boulevard Konrad Adenauer L-2950 Luxembourg Luxembourg	Tel : +352 4379 4911 Fax : +352 4379 6698	collin@eib.org
11	**European Investment Bank (EIB)**	Mr. Klaus Heege Projects Department, Aviation Projects		Tel: +352 4379 2699 Fax: +352 437704	k.heege@eib.org
12	**GAMBIA** **Gambia Civil Aviation Authority**	Ms. Catherine Nying Director of Airport Operations	PMB 285 Banjul International Airport, Yurdum , Gambia	Tel: 220 4472 846 Fax: 220 4472 190	daops.gcaa@qanet.gm kathy@qanet.gm

N	STATE/ORGANIZATION	NAME/DESIGNATION	ADDRESS	TELEPHONE/FAX	E-MAIL
13	**ESYS plc**	Ms. Nina Costa	1 Occam Court Surrey Research Park Guildford GU 2 YHJ - UK	Tel: +39 011 9132069 Fax: +39 011 9132069	ncosta@esys.co.uk
14	**European Space Agency (ESA)**	Mr. Martin Ditter	ESA/EGNOS Projects Office Center Spatial de Toulose – Batiment Ariane 31401 Toulouse Cedex9, Fance	Tel : +33 5 6127 3048 Fax : +33 561282866	martin.ditter@esa.int
15	**European Space Agency (ESA)**	Mrs. Micheline Tabache	ESA Headquarter International Relations 8-10 Rue Mario Nikis 75015 Laris, France	Tel : +33 1 53697304 Fax : +33 1 53697627	micheline.tabache@esa.int
16	**European Space Agency (ESA)**	Mr. Phillippe Michel	ESA/EGNOS Projects Office Center Spatial de Toulose 31401 Toulouse Cedex9, Fance	Tel: +33 1 561283180 Fax: + 33 5 61273048	phillippe.michel@esa.int
17	**AMATHOLE GROUP**	Mr. Jaap Van Der Merwe CEO (RAIL)	P. O. Box 666 Broederstroom 0240 South Africa	Tel: +27 832861925 Fax: +27 11 6566110	jaap.vdm@amathole.com
18	**AMATHOLE GROUP**	Mr. Gus Klohn	P. O. Box 666 Broederstroom 0240 South Africa	Tel: +21 834451274 Fax: +21 11 6566110	gus.klohn@amathole.com
19	**CAMEROON** **Cameroon Civil Aviation Authority**	M. Jean Pierre Kouogueu	BP 6998 Yaoundé République du Cameroun	Tel : +237 2303090 Fax : +237 9685666	jpkouogueu@hotmail.com

N	STATE/ORGANIZATION	NAME/DESIGNATION	ADDRESS	TELEPHONE/FAX	E-MAIL
20	**BH SOLICITORS**	Dr. Kofi Henaku	6 Devonshire Road London SE 23 3TJ UK	Tel: +44 2082918570 Fax: +4 42082918579	khenaku@bhsolicitors.com
21	**KENYA** **Kenya Civil Aviation Authority**	Mr. William N. Omolo Chief Technical Officer	P. O. Box 30163 00100 Nairobi Kenya	Tel : +254 020 827407 Fax :+254 020 822300	kcaa@nbnet.co.ke
22	**GUINEA** **ROBERTS FIR**	Mr. S.T.A. Bangura Deputy Secretary General for Technical	B.P. 5294, Conakry, Guinea	+224 40 4374	stbangura@yahoo.com
23	**GUINEA** **ROBERTS FIR**	Mr. Walter H.T. Wilson Deputy Secretary General for Adminstration	B.P. 5294, Conakry, Guinea	+224 40 4373	hammadwilson@yahoo.com
24	**SOUTH AFRICA** **Air Traffic & Navigation Services Company Ltd. (ATNS)**	Mr. Carel Gersbach	Old Mutual Business Park, Gewel Street, Isando Ext. 3 South Africa	Tel: +27 11 961 0218 Fax: +27 11 392 3969	carelg@atns.co.za
25	**SOUTH AFRICA** **Air Traffic & Navigation Services Company Ltd. (ATNS)**	Mr. Leon Nel	Old Mutual Business Park, Gewel Street, Isando Ext. 3 South Africa	Tel: +27 11 961 0229 Fax: +27 11 392 3969	leonn@atns.co.za
26	**SOUTH AFRICA** **Air Traffic & Navigation Services Company Ltd. (ATNS)**	Ms. Susan Britts	Old Mutual Business Park, Gewel Street, Isando Ext. 3 South Africa	Tel: +27 11 961 0324 Fax: +27 11 392 3969	susannb@atns.co.za

N	STATE/ORGANIZATION	NAME/DESIGNATION	ADDRESS	TELEPHONE/FAX	E-MAIL
27	**SADC**	Ms. Judith Nwako	Private Bag 0095 Gaborone Botswana	Tel: +2767 3951863 Fax: +267 3972848	jnwako@sadc.int
28	**Galileo Joint Undertaking (GJU)**	Mr. Giorgio Solari	Rue du Luxembourg 3 B-1000 Bruxelles Belgium	Tel : +32 2 5078039 Fax : +32 2 50780001	Giorgio.solari@galileoju.com
29	**GHANA** **Ghana Civil Aviation Authority**	Mr. David Twum Antwi Ag Director of Finance	Private Mail Bag Kotoka Int'l Airport Accra Ghana	Tel: + 233 21 775096 Fax: +233 21 773293	twumantwi@gcaagh.com
30	**GHANA** **Ghana Civil Aviation Authority**	Mr. Prince B. Boateng Ag. Director of Engineering	Private Mail Bag Kotoka Int'l Airport Accra Ghana	Tel: + 233 21 760596 Fax: + 233 21 773293	pbboateng@gcaagh.com pbboateng@yahoo.co.uk
31	**GHANA** **Ghana Civil Aviation Authority**	Mr. Orhin William Ag. Deputy Director General (Finance & Administration)	Private Mail Bag Kotoka Int'l Airport Accra Ghana	Tel: + 233 21 777476 Fax: +233 21 773293	wohin@gcaagh.com willorh@yahoo.com
32	**GHANA** **Ghana Civil Aviation Authority**	Mr. Edwin Addo Director of Air Traffic Services	Private Mail Bag Kotoka Int'l Airport Accra Ghana	Tel: + 233 21 776079 Fax: +233 21 773293	edwin_addo@yahoo.com
33	**ASECNA**	M. Sadou Marafa Directeur de l'Exploitation	32-38 Av Jean Jaures BP 3144 Dakar Senegal	Tel : +221 8 695679 Fax : +221 8207495	marafasad@asecna.org

N	STATE/ORGANIZATION	NAME/DESIGNATION	ADDRESS	TELEPHONE/FAX	E-MAIL
34	**ASECNA**	M. François-Xavier Salambanga Chef du Service Exploitation des Telecommunications	Aeroport LSS. BP 8163 Dakar Senegal	Tel : +221 8695749 Fax : +221 8207538	salambangafra@asecna.org
35	**Arab Civil Aviation Commission (ACAC)**	Mr. AbdelLatif Lahboubi, Director of Air Navigation	48 Alkhssass st. Iman Malik Avenue, Souissi, Rabat Morocco	Tel: 212 61405320 Fax: 212 37658111 Fax: 212 37658154	lahboubi@acac.org.ma
36	**ICAO**	Mr. Mamadou Traore, Regional Officer CNS, Cairo Office	ICAO Regional Office Cairo , Egypt	Tel: 202 2674841 Fax: 220 2674843	mtraore@cairo.icao.int
37	**ICAO**	Mrs. Mary A. Obeng, Regional Officer CNS, Dakar	15 BO de la Rep. B.P 2356 , Dakar Senegal	Tel : 221 8399388 Fax : 221 8236926	mobeng@icao.sn
38	**ICAO**	Mr. Amadou Sene, Regional Officer CNS, Nairobi Office	P.O Box 46294 00100 Nairobi Kenya	Tel : 254 20 762 2367 Fax : 254 20 7621092	amadou.Sene@icao.unon.org
39	**COMESA**	Mr. Amos Marawa	Ben Bella RD Box 30051 Lusaka , Zambia	Tel: 260 -1- 227322 Fax: 260 -1- 225107	amarawa@comesa.int
40	**Mauritius**	Mr. Iswarduth Pokhun Divisional Head (CNS)	Department of Civil Aviation SSR International Airport – Plaine Magnien - Mauritius	Tel: 230 603 2000 Fax: 230 6373164	ipokhun@mail.gov.mu

N	STATE/ORGANIZATION	NAME/DESIGNATION	ADDRESS	TELEPHONE/FAX	E-MAIL
41	**NIGERIA** **Nigerian Airspace Management Agency** **(NAMA)**	Mr. Godfrey U. EZE, Nigerian Airspace Management Agency	Murtala Muhammed Airport, P.M.B. 210841, Ikeja Lagos, Nigeria	Tel/Fax: +234 01 493 3356 2348055096104	godfreyudenna@yahoo.com
42	**NIGERIA** **Nigerian Airspace Management Agency** **(NAMA)**	Mr. Olayiwola Fatimilehim, Nigerian Airspace Management Agency	Murtala Muhammed Airport, P.M.B. 210841, Ikeja Lagos, Nigeria	Tel/Fax: +234 01 493 2608	layifatimilehim@yahoo.uk.co
43	**NIGERIA** **Nigerian Airspace Management Agency** **(NAMA)**	Mrs. Maureer Tamuno	Murtala Muhammed Airport, P.M.B. 210841, Ikeja Lagos, Nigeria	Tel: 080 355 22 091	maureentamuno@yahoo.com
44	**Dubai Consultancy Research Centre**	Prof. Anwar Dawood	PO Box 57578 Dubai United Arab Emarites	Tel: + 971 4 332 3000 Fax: + 971 4 331 4666	adawood@dubaiconsultancy.ae
45	**Dubai Consultancy Research Centre**	Eng. Amer Al Sayegh	PO Box 57578 Dubai United Arab Emarites	Tel: + 971 4 332 3000 Fax: + 971 4 331 4666	amer@dubaiconsultancy.ae
46	**ESSP**	Mr. Patrice . y. Bouedo	240 Avenue Louise 1050 Brussels Belgium	Tel : +34 629 620 023	Patrice.bouedo@essp.be

ISA Potential Investors Workshop
(Cairo, 14-15 February 2006)

Agenda

Tuesday 14 February 2006 – Introducing ISA

#	Agenda Item	Schedule	Who
	Welcome addresses	9.00 -9.30	Mr Ahmed, Chairman of NANSC and Mr Khonji, Regional Director, ICAO Cairo Office
1	Introduction and meeting objectives	9.30-10.30	Giorgio Solari, GJU and Amadou Sene, ICAO
2	EGNOS Status in North Africa	10.30-11.00	Mohamed Elkady, Director of GEMCO
	Coffee/tea	11.00-11.30	
3	Planned implementation time frame	12.00-12.30	Giorgio Solari, GJU and Philippe Michel, ESA
4	ISA Final Architecture and costs – Questions/answers	11.30-12.00	Phillippe Michel, ESA
	Lunch	12.30-14.00	
5	ISA Benefits analysis – discussion	14.00-14.30	Nina Costa, ProDDAGE
6	SBAS GNSS Receivers	14.30-15.00	Patrice Bouedo, GJU expert
	Coffee/tea	15.00-15.30	
7	Report from the AFI GNSS Implementation Task Force – proposed ISA institutional framework – feedback from APIRG 15	15.30-16.00	Amadou Sene, ICAO

Wednesday 15 February 2006 – ISA Realisation

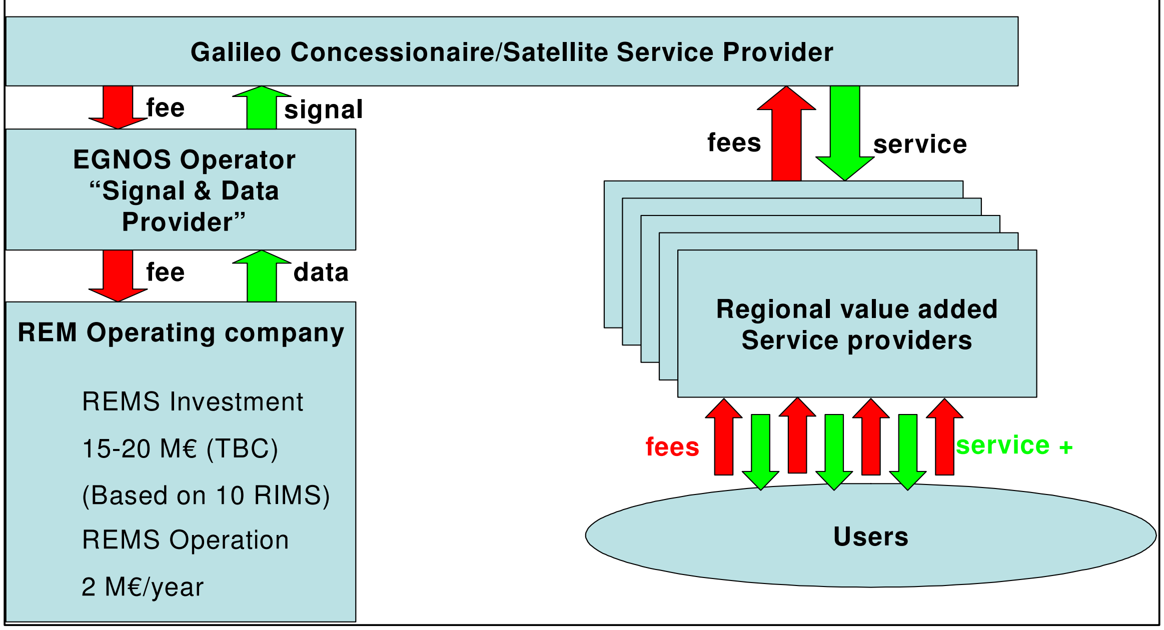
#	Agenda Item	Schedule	Who
8	ISA legal issues – discussion	9.00-9.30	Kofi Henaku, Bilson Henaku Solicitors
9	Funding options	9.30-10.00	Nina Costa, ProDDAGE
10	Loan applications	10.00-10.30	Catherine Collins, EIB
11	RIMS hosting – what this means for the host country – discussion	10.30-11.00	Martin Ditter, ESA
	Coffee/tea	11.00-11.15	
12	VSAT model of service provision – advantages of VSAT extension – possible contractual and legal framework	11.15-12.00	Leon Nel, ATNS François-Xavier Salambanga, ASECNA
13	Tour de table – statements of intention	12.00-13.00	ATS providers
	Lunch	13.00-14.00	
14	Agreement of a way forward for ISA implementation – identification of obstacles or impediments – next steps Drafting of meeting resolution	14.00-15.30	All ICAO/GJU
	Coffee/tea	15.30-15.45	
15	Agreement of meeting resolution	15.45-16.30	ICAO/GJU

Workshop Conclusions Viewgraphs

Clarification on EGNOS Lifetime

- EGNOS will operate simultaneously with Galileo
- EGNOS Operations will last up to 2025 at least
- Future GNSS evolution perspective contemplate monitoring of the Galileo constellation by SBAS system

EGNOS ISA Business model



Workshop main conclusions

- Participants reiterate their interest in the possible implementation of a SBAS in AFI (ISA) based on the REM concept presented by GJU/ESA
- Participants confirm that the REM concept as presented would allow meeting the objectives set by the AFI GNSS strategy
- Participants take note of the ongoing study on this REM concept conducted by ESA and request ESA to confirm the budgetary and technical information to be provided to the participants by end April 2006.
- Participants express their interest in the development by ESA of the EGNOS interface allowing to connect the AFI REM nodes and encourage the GJU and ESA to confirm the implementation scenario in the timeframe 2007 to 2008.
- Based on the above, participants agreed that:
  - Sub-regional groups as identified by APIRG 15 be promptly set up with the objective to elaborate road maps for the implementation including funding structure of ISA, with involvement of relevant regional economic organisations. Each sub-regional group should produce implementation scenarios by end June 2006.
  - An ISA steering group be created to coordinate and harmonise the work of three sub-regional groups and ensure liaison with MEDA and Middle East interface

Subregional Group TORs

- Bring together the sub-regional stakeholders (ATS providers and regional economic groupings)
- Establish sub-regional programme proposals including:
  - REM implementation plan
  - Funding options
  - List of agreements to be established
- Facilitate progress towards subregional institutional and regulatory set-up
- Report on progress to steering group

•Subregional group coordinators

- Sub-region 1: Western/ Central Africa (e.g., AFISNET).
  - Coordinators:
    - Ghana: Prince Boateng
    - ASECNA: Sadou Marafa
- Sub-region 2: Southern Africa.
  - Coordinator: ATNS: Leon Nel
- Sub-region 3: Eastern Africa
  - Coordinator: KCAA: William Omolo

Subregional groups short term actions

- Review outcome of ESA architectural study
- Establish draft Subregional REM implementation programme
- Identify list of open issues to enable decision making
- Draft recommendations / solutions for each of the above issues
- Report to the steering group by end of July 2006

Steering group composition

- Ghana, ASECNA, KCAA, ATNS

- ACAC
- AFCAC
- GEMCO
- GJU
- RECs (Regional Economic Communities)
- User Groups
- Coordinator: ICAO

International Civil Aviation Organization

First Meeting of the APIRG Communications, Navigation and Surveillance Sub-group (CNS/SG/2)
(Dakar, 22-25 May 2007)

APPENDIX B TO WP/17

ProDDAGE
Galileo Joint Undertaking

Inter-regional SBAS for Africa - Review of benefits and costs

PROD-HELIOS-DD-06.1

HELIOS TECHNOLOGY

ESYS

ESSP

ERTICO
INTELLIGENT TRANSPORT SYSTEMS AND SERVICES-EUROPE

BOMBARDIER TRANSPORTATION

NSL

THALES
Thales GeoSolutions Group Ltd

ALCATEL SPACE

ECORYS
Research and Consulting

Inter-regional SBAS for Afr

Reference: PROD-HELIOS
Commercial in Confidence

Documen

Client:

Project Number:

Contract Number

Amendment Record

Issue	Revision	Date	Details
Draft	A	08/10/2004	First draft.
Draft	B	17/01/2005	Second draft
Final	A	26/04/2005	Issue for final review
Final	B	26/05/2005	Issue for release
Final	C	26/01/2006	Addition of chapter 5
Final	D	26/05/2006	Issue for release
Redraft	E	29/09/2006	Redraft of above revision D
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Executive Summary

This report examines some of the benefits and costs of an Inter-regional SBAS over the African and Indian Ocean (AFI) region (ISA). It has been carried out as part of the Programme for the Development and Demonstration of Applications of Galileo and EGNOS (ProDDAGE) project on behalf of the Galileo Joint Undertaking (GJU).

The report is intended to inform the GJU in its development of the ISA and will support the business case for further capital investment.

Some of the greatest benefits of an ISA are most likely to arise from Safety of Life (SoL) applications. Already, the aviation interest in Space Based Augmentation System (SBAS) in this area is substantial, evident by the recent work of the GJU and various other studies and trials. As a result, this report has concentrated on the aviation domain.

There are several reasons for implementing an ISA, which include the safety, operational and economical benefits derived from the performances that will be provided in terms of integrity, continuity, availability and accuracy. These benefits are very important for the African aviation industry considering that is a large geographic area with a low density of navaids. Moreover, the proximity of Africa to Europe simplifies the system implementation as it will be based on the deployment of new instances of already exiting developments (e.g. only recurrent costs of procuring additional RIMS) and the GEOs satellites used in Europe already cover Africa.

This report quantifies the cost savings derived from the following as a result of the implementation of an ISA:

- Improvements in flight safety;
- the phasing out of some ground-based navigation aids; and
- the use of SBAS for Approach with Vertical Guidance (APV).

SBAS-based APV approach procedures could be offered in conjunction with barometric vertical navigation (Baro-VNAV) APV approaches as an alternative to Non-Precision Approaches (NPAs) or, in some cases, ILS CAT I. APV approaches using either SBAS or Baro-VNAV overcome many of the disadvantages of non-precision approaches without the need for airport-based ground infrastructure. APV SBAS is complementary to APV Baro-VNAV and both types of approach should be made available where applicable.

Both the airlines and the Air Navigation Service Providers (ANSPs) will benefit from the cost savings. The report then examines the cost for the user community in provisioning the AFI fleet with SBAS capability. Scenarios are also investigated for the costs of the necessary ground infrastructure.

Potential cost savings for the above mentioned benefits are estimated at €516M Net Present Value (NPV), over the period 2005-2025. In the early years annual savings are of the order of €1.4M rising to over €40M by 2025.

Where aircraft are not already capable of APV Baro-VNAV, the cost of equipping them with APV SBAS is estimated at €31M NPV. This is the cost of ensuring that all aircraft can perform APV approaches (of one sort or another) by 2015. Estimates of the total cost of implementing and operating the ground infrastructure of SBAS, including financing costs, are between €100-180M NPV for the period 2005-2025.

The cost savings of over €500M NPV therefore considerably outweigh the deployment costs of about €210M maximum.

Based on a promising set of benefits, the business case should be further elaborated to help support the assessment of the key stakeholders and decision makers in implementing ISA. A review of the additional safety benefits should be considered. In addition, we recommend further study of the benefits for other SoL communities.

In assessing the data for this work, difficulty was had in obtaining correct, unambiguous and up-to-date data so as to perform a more detailed report. For a more comprehensive justification, current information on the following should be obtained:

- operating costs of existing navigation infrastructure;
- annual revenues from air navigation charges;
- equipment costs for current ground navaids;
- exact numbers of ground navaids in operation;
- numbers of African to non-African international aircraft operating in AFI airspace.

Contents

1. Introduction

1.1 General

This report discusses some of the benefits and costs of an Inter-regional SBAS over the Africa and Indian Ocean (AFI) region (ISA). The document is intended to inform the Galileo Joint Undertaking (GJU) in its development of the ISA and will support the business case for further capital investment. The document focuses upon identifying and exploring some of the key issues that affect any future investment:

- Operational benefits of the introduction of SBAS;
- Investment cost;
- Annual operational costs;
- Topics for further investigation to support decision makers at all levels.

Much of the work to date on SBAS has an aviation focus, but benefits are also anticipated for other sectors. In this work we have taken a multi-modal view of SBAS in Africa but only considered the aviation applications in detail.

1.2 ProDDAGE

The work has been carried out as part of the ProDDAGE project, as part of the Galileo 6th framework first call (issued in 2003). ProDDAGE is the PROgramme for the Development and Demonstration of Applications for Galileo and EGNOS and is overseen by the GJU. This document was originally issued in early 2005 and following receipt of comments an additional section has been added. The additional section examines the cost of SBAS equipage to the African fleet and has been included as chapter 5.

1.3 Overview of the AFI Region

The map below shows the member states of the ICAO WACAF (Western and Central African) region, which consists of 24 contracting states in the AFI region, and the ICAO ESAF (Eastern and Southern African Office), which consists of 23 contracting states. Also shown are the ASECNA member states.

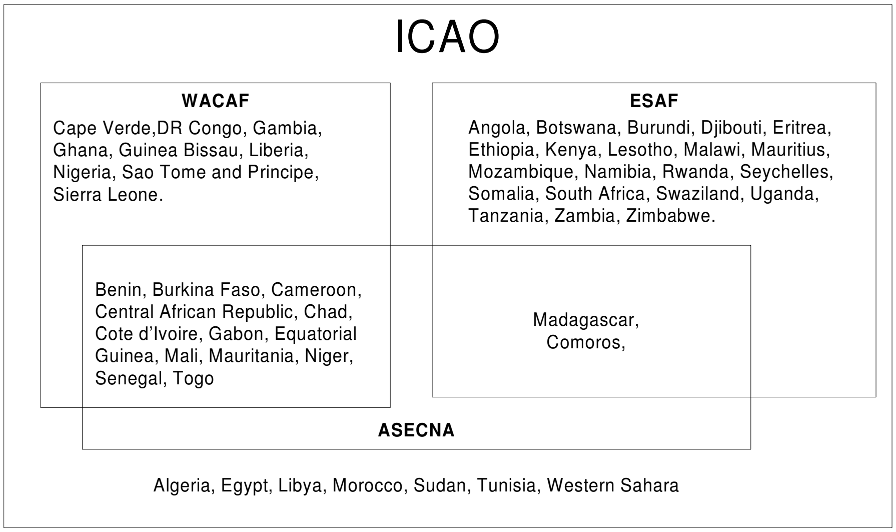

Figure 1: African member states

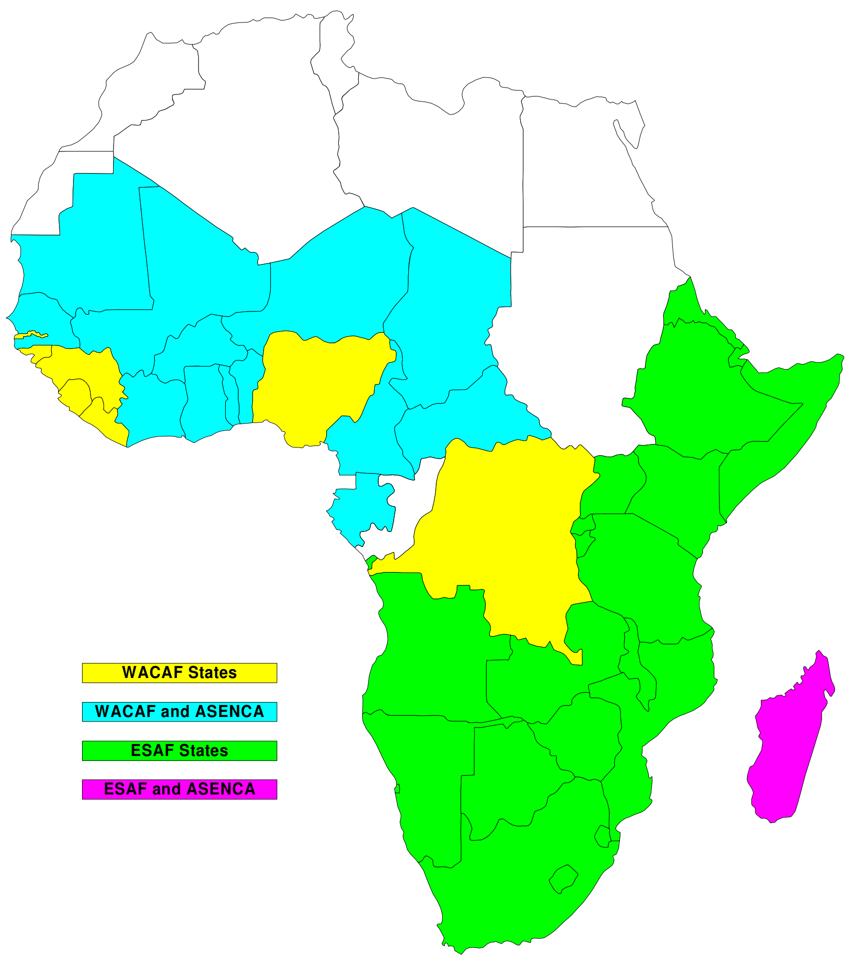

Figure 2: Map of the AFI region

1.4 Overview of EGNOS plans for Africa

The Galileo Joint Undertaking (GJU) has an objective to develop an Inter-regional SBAS over the Africa and Indian Ocean (AFI) region (ISA). The European Commission has co-funded a number of studies and trials activities in the region, in collaboration with many regional partners, including ICAO, IATA, ASECNA and the Republic of South Africa's ATNS. These efforts have a strong context in regional development policy as well as international aviation, where the development of GNSS is a fundamental enabler for the future air navigation system [1].

The plans for extending the EGNOS service to Africa have been largely led by the aviation community through Africa's regional ICAO Groups. In June 2003 an ICAO regional planning meeting, APIRG, concluded that an operational SBAS system be implemented in Africa as an extension of EGNOS and that financial support would be sought through African regional economic organisations [2]. This meeting also reported on the successful flight trials of the EGNOS testbed in Cameroon, Nigeria and Gabon.

Following this meeting a task force was established to manage the implementation of ISA (Inter-regional SBAS for Africa) to the pre-operational and operational levels. Since then, a full test programme has been implemented across the entire region - the outcome of which has been very successful. A final flight trial took place in May 2005 from Dakar to Nairobi under the auspices of the GJU ProDDAGE contract in collaboration with ESA and ASECNA. The technical description and outcome of this trial is reported in ProDDAGE Deliverable D13.1[1]. The EGNOS testbed over Africa was terminated at the end of June 2006.

The proposed SBAS service level for Africa is Approach with Vertical Guidance I, or 'APV I'. This is a level of service suitable for aircraft operations, both in en-route and approach. ICAO (OCP group) is currently defining procedures design criteria for APV operations. And the French DGAC has involved ASECNA in the APV procedures development.

1.5 Review of previous cost benefit studies of SBAS in Africa

In parallel with work on EGNOS costs and benefits in Europe, a number of other studies considering benefits in Africa have been carried. These are as follows:

- A European Commission Framework funded study of the introduction and implementation of GNSS in the African and Indian Ocean Region, which was carried out in two phases [2, 3].
- A Eurocontrol study [4], which considered the aviation case for EGNOS in Africa.

The Commission study examined the benefits of GNSS in two main ways. Firstly it addressed the benefits of avoiding flight diversions due to poor weather conditions. This assessed the marginal benefits of a GNSS service over existing NPA procedures. Secondly, it considered the benefits of withdrawing NDB/L, VOR and DME. These were estimated to be $242M over the period 2000 – 2010. This value is the NPV of the benefits over that time period. The study did not value the benefits of avoiding diversions; however, this was addressed in the Eurocontrol study.

[1] PROD-ESSP-DD-13.1 v3, ASECNA Flight Trials in AFI Zone C Report

The Eurocontrol study built on the work of the Commission study and identified the operational value of APV I over NPA in terms of avoided diversions. This was valued at €128M for the period 2005 – 2020 [4]. It was based on a composite cost of disruption of €1638 per flight; assuming delay, diversion or cancellation. The Eurocontrol study also cited two further benefits, which were not valued:

- improved navigation coverage to areas currently lacking in conventional aids;
- improved vertical guidance and thereby safety on approach.

The current ProDDAGE document also quantifies the benefits of avoided diversions and reduced navigation infrastructure. But it goes further than the Eurocontrol study and financially quantifies the benefit of improved safety, although caution is needed in interpreting these.

2. Acronyms and abbreviations

ADS	Automatic Dependent Surveillance
AFCAC	African Civil Aviation Commission
AFI	Africa and Indian Ocean region
AIS	Aeronautical Information Service
AIS	Automatic Identification System
ANSPs	Air Navigation Service Providers
APIRG	AFI Planning and Implementation Regional Group
APV	Approach with Vertical Guidance
ASECNA	L'Agence Pour La Sécurité De La Navigation Aérienne En Afrique et a Madagascar
ATNS	RSA Air Traffic and Navigation Services
B-RNAV	Basic RNAV
CAA	Civil Aviation Authority
CANSO	Civil Air Navigation Services Organisation
CBA	Cost Benefit Analysis
CRCO	Central Route Charging Office
DGAC	Directorate General d'Aviation Civile
DGNSS	Differential GNSS
DGPS	Differential GPS
DME	Distance Measuring Equipment
ECAC	European Civil Aviation Conference
EGNOS	European Geostationary Navigation Overlay System
GBAS	Ground Based Augmentation System
GJU	Galileo Joint Undertaking
GLA	General Lighthouse Authority
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
IATA	International Air Transport Association
ICAO	International Civil Aviation Organisation
ILS	Instrument Landing System
IMO	International Maritime Organisation
INS	Inertial Navigation System
ISA	Inter-regional SBAS over AFI
NDB	Non Directional Beacon
NOTAM	Notice to Airmen
NPA	Non-precision approach
ProDDAGE	Programme for the Development and Demonstration of Applications of Galileo and EGNOS
RAIM	Receiver Autonomous Integrity Monitoring
RIMS	Ranging and Integrity Monitoring Stations
RNAV	Area Navigation
RNP	Radio Navigation Parameters
SAMSA	South African Maritime Safety Authority
SBAS	Space Based Augmentation System
VNAV	Vertical Navigation
VOR	VHF Omni Directional Range / Radio
VOSL	Statistical Value of Life
WAAS	Wide Area Augmentation System
WWRNS	World Wide Radio Navigation System (IMO)

3. ISA Applications suitable for the AFI region

3.1 General

This section identifies the potential applications of SBAS in the AFI region from a *multi-modal* perspective and considers what cost recovery mechanisms might be exploited for ISA.

We began our study by a systematic analysis of the performance requirements of different applications. We compared the requirements of a range of applications derived from the European Radio Navigation Plan [5] with APV I[2] performance levels. Our aim was to identify applications which require one or more of the APV I performance requirements to be met. However, this approach did not yield any particularly useful information. For instance, it did not identify ISA as a potential alternative to DGPS for maritime use; although clearly there are such benefits.

We therefore drew on existing knowledge from the ProDDAGE[3] market study and in particular Issue 1 of the Application and Service Development Plan (ASDP). This has identified a number of applications that may generate significant downstream benefits in the aviation, maritime and rail domains.

The remainder of this section summarises the impact of SBAS in the context of the operations of aviation, maritime and rail users. It then discusses how the service costs are recovered from users and whether there are any existing cost recovery mechanisms that might be exploited for ISA.

3.2 Enabled applications

The impact of the applications discussed in the preceding section is now discussed in terms of their respective markets.

3.2.1 Aviation

There are clear problems with the availability and coverage of navigation aids of the AFI region. A simple comparison may be made with Europe (ECAC). ECAC has around three thousand en-route navigation aids for an area of 12 million km^2 sq. km. Africa has around 600 en-route navigation aids for an area of 31 million km^2. Ie the density of navigation aids in Europe is about twelve times that in Africa. This is not a like for like comparison, as the true need for navigation aids depends on the aviation route structure derived from the airspace capacity requirements. Nevertheless, SBAS promises less reliance on these sparsely populated navigation aids, which have low reliability and are sometimes difficult to site in remote areas with terrain masking.

[2] A similar approach with a slightly higher level of performance (APV II) has also been defined. However, EGNOS would only support APV I in the AFI region, so this report focuses on that.

[3] ProDDAGE – Application and Service Development Plan (ASDP) Issue 1, 15/10/2004.

For example, the replacement of Non-Precision Approaches (NPA) by SBAS-based Approaches with Vertical Guidance (APV) is seen by ICAO as an important step in improving the safety of approach operations. The ICAO 11th Air Navigation Conference recommended that:

- ANSPs in conjunction with airspace users move fast to achieve a worldwide navigation capability of at least APV I performance.
- States and airspace users take note of upcoming SBAS navigational services providing for APV operations and move towards installation and certification of SBAS capable avionics.

APV approaches will be flown to a lower decision altitude than NPAs and, hence, improve airport capacity in adverse weather conditions (although the probability of such conditions in the AFI states is low). They can eliminate the “dive and drive” aspect of NPAs and give the safety benefits of vertical guidance, without the requirement for a ground system at the airport. The various levels of approach operations have different decision heights as illustrated in the following table:

Operation	Minimum Decision Height (ft)
NPA	350 – 400
APV Baro-VNAV	300 – 350
APV I & II	200 – 250

Table 1: Typical expected MDHs of NPAs and APVs

SBAS may also support new surveillance technologies such as ‘Automatic Dependent Surveillance’. These enable aircraft positions to be communicated to air traffic control by point-to-point or broadcast datalinks. SBAS may not be a pre-requisite but it may encourage the implementation of ADS given its high integrity position.

3.2.2 Maritime

Augmented GPS is used for ocean navigation, coastal navigation, port approaches and inland waterways. Although not formally recognised via the World Wide Radio Navigation System (WWRNS) by the International Maritime Organisation (IMO), the IALA DGNSS system represents the default solution and is the primary means of navigation in those areas of coastal coverage. ISA could be a cheaper alternative to DGPS for future implementations (new sites or replacements) as well as providing a potential improvement in performance, both in terms of accuracy and integrity (see paragraph 3.10 below). We have identified the following stations for the AFI region[4]:

- South Africa has four DGNSS stations on trial and a further one planned.
- Egypt has six stations in operation.
- Tunisia has one DGNSS.

Nominal ranges are around 300km. There is clearly little DGPS coverage around most of Africa, nor any in the Eastern Mediterranean. ISA could provide a similar operational service. It is also likely to provide a more uniform service than that provided by DGNSS because it has been designed to minimise the impact of spatial de-correlation that is inherent in most DGNSS services. SBAS data could be provided over existing communication links to overcome potential limitations of geostationary

[4] IALA, ‘DGNSS reference and transmitting stations in the maritime radionavigation (radiobeacons) band’, issue 8, September 2002. Found at: http://site.ialathree.org/index.html

satellites. It could also be transformed into the required RTCM format to be used by existing DGPS receivers. These operational advantages would also apply for inland waterways.

Another role of DGPS and potentially SBAS, is the provision of positioning for Automatic Identification Systems (AIS) for a stable and precise display of a vessel's speed and course.

Analysis of the potential maritime applications is currently being undertaken as part of the GJU ProDDAGE contract. Once finalised, these results will be made available and their application to the African region determined. In the future, and on the basis of these results, the case for the maritime community will be assessed in more detail and may be incorporated in future versions of this document.

3.2.3 Rail

The high level of integrity of ISA may support improved train control. In many parts of the world, including Africa, single track railways are important carriers of goods and people. However, track-side infrastructure is vulnerable (because it is not protected) and in many cases the signalling systems (ie rail control systems) are old and under-invested.

A combination of ISA services with complementary capability such as that provided by odometers could provide a total on-board solution that satisfies performance requirements sufficient to meet certain safety levels.

Also, fail-safe satellite positioning systems developed for trains, may be used as part of a train control system for low density traffic lines. The primary benefit is that the cost of trackside equipment would be substantially reduced. ISA would be able to provide positioning information of each train continuously and in real time which, when linked to a central control centre would allow control instruction (stop/go/continue etc) to be sent to each train.

Train control applications have already been recognised (GALA and Galilei under the title "Train Supervision"), and for this application, whilst positioning accuracy of the train on the track is not that stringent, a great deal of emphasis is placed on integrity with failure warning and high availability. ISA could bring about these benefits. It should also be noted that a demonstration campaign has already been proposed in ProDDAGE.

Analysis of the potential rail applications is currently being undertaken as part of the GJU ProDDAGE contract. Once finalised, these results will be made available and their application to the African region determined. In the future, and on the basis of these results, the case for the rail community will be assessed in more detail and may be incorporated in future versions of this document.

3.3 Revenue streams

EGNOS has been designed to meet the demanding performance requirements for aircraft navigation, as well as having the performance potential to support a number of maritime and mass-market applications. The EGNOS SIS is currently provided openly to the, and cost recovered from its use must therefore depend upon a mixture of regulation and/or institutional recovery mechanisms.

This issue is beyond the scope of this particular study but must be kept in mind when considering charging for the EGNOS service. In the case of aviation, for example, EGNOS service charges are likely to be collected via Air Navigation Service Providers (ANSPs). The interface between the ISA service provider and the local ANSPs has to be developed.

The following sections discuss cost recovery mechanisms.

3.3.1 Air navigation service cost recovery

Air navigation service costs are typically recovered through en-route and terminal navigation charges. Often terminal charges may be consolidated into en-route or aerodrome charges or landing fees. World-wide, most ANSPs operate a cost recovery system. There are some exceptions where costs are borne by general taxation or allow a profit component.

For the AFI region, the relevant implementation and operating costs of ISA could be shared among air navigation service providers with low impact to existing charges. The ISA service provider would have a direct relationship with each ANSP, for the provision of the signal in space against a service level agreement.

Airspace users will therefore face investment costs for the avionics equipage and an increase in charges for the air navigation investment and operating. The rate of equipage may be slow without a strong cost benefit case. However, users may find the safety arguments compelling once the service is in operation, accelerating take-up.

A trend to consider is the outsourcing of charges collection. For example, Eurocontrol's Central Route Charges Office (CRCO) now collects charges for Egypt and Morocco. There is also a trend for project finance debt to be recovered directly from the user charges giving added surety to the lenders.

Some of the AFI states also use the IATA E&F[5] (enhancement and financing) service as means of collecting all Air Navigation and Airport-related charge. Other states and territories in the AFI region use a centralised agency, ASECNA (Agency for the Security of Air Navigation in Africa and Madagascar), for the collection/recovery of air navigation charges.

3.3.2 Maritime cost recovery

In general terms, the costs of coastal navigation services are not met through an equivalent cost recovery mechanism from commercial vessels, either at a national or regional level. There are a few exceptions to this, namely:

- In the UK, these are paid into the General Lighthouse Fund (GLA), under the Department for Transport;
- South Africa, where funding for the South African Maritime Safety Authority (SAMSA) comes from sources such as levies on ships, direct user charges and government service fees.

These same mechanisms do not apply to the AFI region on an international basis and would therefore require bespoke institutional arrangements and associated regulation.

[5] http://www.iata.org/PS/SERVICES/EFSERVICES

3.3.3 Rail cost recovery

Rail is typically funded by operating revenues, subsidised by Governments (tax receipts) at a national level.

3.4 Summary of suitable applications

For aviation, maritime and rail, SBAS offers the potential for service providers and users to be less reliant on existing navigation infrastructure. It also offers an increase in safety and has the potential to support surveillance: ADS for aviation and AIS for maritime. Therefore, our initial assessment is that aviation and maritime markets specific to the AFI region could derive the most immediate benefit from ISA.

The aviation domain already has revenue collection mechanisms in place to recover costs from users. SBAS may offer justifiable costs and benefits to the controlling organisations that make only a marginal difference to user fees. Therefore a revenue collection model for ISA may be to build a small group of organisations from key countries[6] [6] with mature charges collection schemes.

Given the clear interest and potential for revenue generation in aviation we have focused the remainder of this report on the aviation domain. We would nevertheless recommend more detailed study of the maritime domain, considering SBAS as an alternative or complement to DGPS and an input to AIS, and of the rail domain concerning train control for low density traffic lines.

[6] Both domains support commercial networks across Africa and it could be argued that there is some distribution of charges amongst users across the continent. For example, South African Ports act as shipping hubs for the Southern Africa Development Community (SADC); approximately 95 percent of all trade to the region passes through these ports and those of East Africa.

4. Aviation applications

4.1 Overview

This section focuses on the aviation applications of EGNOS. There is a strong interest in the AFI region to overcome the limitations of conventional navigation aids through satellite navigation augmented by SBAS [7]. In this section we first examine the operational justification for this, before considering what the benefits may be. We conclude by looking at the impact of the costs and benefits in the context of industry revenues.

Amongst the aviation community assessments are ongoing in relation to SBAS, particularly in Europe. A recent CANSO document [8] captured several industry views. These are summarised as follows:

- SBAS is seen as best serving 'low-end' users.
- SBAS will increase safety margins in approach procedures.
- SBAS will provide efficiency benefits on runways not served by ILS.
- SBAS will enable fewer ground aids after 2010.
- SBAS is interesting for approaches with vertical guidance.

These industry views are broadly reflected in the analysis undertaken in this report and in the quantified benefits.

4.2 Overview of Aviation Industry in AFI region

The aviation industry in the AFI region accounts for about 3% of the world traffic movements (ACI annual summary for 2003) – see Table 2.

	Central Africa	Eastern Africa	Northeast Asia	Northern Africa	South Asia	Southeast Asia	Southern Africa	Southwest Pacific	Western Africa
Central Africa	19427	1004		52			1986		5527
Eastern Africa		113803	427		1777	266	7,441	161	1,006
Eastern Europe				4016			176		329
Lower South America							752		421
Middle East	147	6429		28370			961		604
North America				1289			805		1041
Northern Africa		1447	506	68636	104	272	515		1852
Southern Africa			1622		286	556	183970	676	
Upper South America									18
Western Africa							1861		54997
Western Europe	2130	11023		74369			11875		13368

Table 2: 1998 traffic movements between sub-regions [9]

The total movements for 1998 in Africa were 638200. Although this data is not current, it gives an indication of the major destinations and routes being flown, and we can assume a similar proportion of movements to these regions based on today's movement figures. Passenger, cargo and movement statistic[7] compiled, as at 16/07/2004, by the ACI are shown in Table 3. This compares African ACI members with the rest of the world ACI members. Passenger numbers in Africa account for 3% of total passenger number for all ACI airports, cargo accounts for only 1% and aircraft movements accounting for only 3%. Aircraft movements include both domestic and international.

STAT	Month	YTD	YE	Change from previous year (%)			% of total ACI
Regions		Apr-04	Apr-04	Month	YTD	YE	
PASSENGERS							
Africa	8 008 164	30 477 938	89 669 922	25.7	15.1	7.7	3
Asia/Pacific	61 048 284	239 917 539	677 341 850	44.6	15.9	4	19
Europe	90 924 589	321 540 957	1 078 824 050	13.5	9.7	5.9	31
Latin America/Caribbean	17 568 303	70 528 192	200 981 970	12.2	11	5.3	6
Middle East	6 300 519	25 411 416	79 051 071	37.4	21.8	12.3	2
North America	122 005 748	452 148 846	1 374 191 744	15.2	8.9	3.4	39
TOTAL	305 855 607	1 140 024 888	3 500 060 607	20	11.1	4.7	100
CARGO							
Africa	81 923	340 228	1 042 485	-9.1	-6.2	-0.4	1
Asia/Pacific	1 916 923	7 295 079	21 395 851	15	13.9	7.6	31
Europe	1 223 561	4 749 756	14 057 414	8.5	6.1	3.4	20
Latin America/Caribbean	272 411	1 025 077	3 068 295	10.3	4.4	-0.5	4
Middle East	268 084	1 053 874	3 115 460	13.7	12.7	11.3	4
North America	2 317 691	9 013 628	27 129 556	6	5.3	1.9	39
TOTAL	6 080 593	23 477 642	69 809 061	9.5	8.1	4.1	100
MOVEMENTS							
Africa	149 062	590 167	1 757 060	8.9	6.3	4	3
Asia/Pacific	569 868	2 245 556	6 400 631	16	9.7	3.9	10
Europe	1 376 403	5 122 683	16 384 347	3.9	1.9	1.1	26
Latin America/Caribbean	323 462	1 303 413	3 792 544	4.6	4.3	-1.3	6
Middle East	71 609	285 060	875 116	13	9.3	10.8	1
North America	2 868 620	11 093 618	33 677 755	3.9	3.1	-0.5	54
TOTAL	5 359 024	20 640 497	62 887 453	5.3	3.7	0.6	100

Table 3: ACI airport statistics 2003/4

According to the Secretary General of the ACI, Mr Alexander Strahl, in November 2002[8] airlines and airports have been hit hard with the decline in air traffic since the events of 9/11 and in Africa, the worst performing airports were located in countries experiencing civil unrest or severe governance problems. Strahl said the African aviation industry, with an expected 3.9% growth per annum through to 2010, is above the world average of 3.4%. Cargo volumes are expected to grow 5.9% per year to 2020, compared to a global expected average of 4.4%. So Cargo will become an increasingly important part of African aviation activities.

[7] **Passengers**: total passengers enplaned and deplaned, passengers in transit counted once. **Cargo**: loaded and unloaded freight and mail in metric tonnes. **Aircraft Movements**: landing or take-off of an aircraft.

[8] The Namibia Economist – 15 Nov, 2002

According to [15], the movement rate in the AFI region is predicted to show a steady and consistent growth up to 2012 and probably beyond as well.

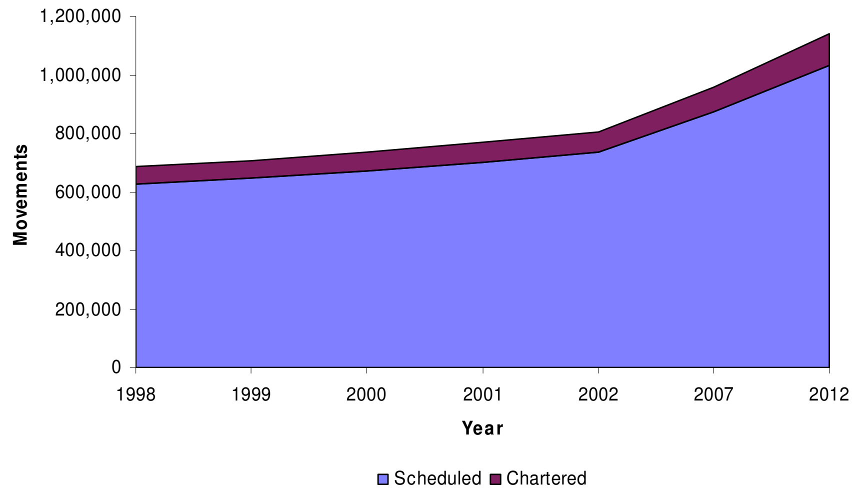

Figure 3: Africa movement forecast

4.3 Operational justification for AFI

There are several areas where SBAS could have an operational justification:

- Overcoming the limitations of conventional navigation systems in the AFI region.
- Increased safety.
- The potential for Approach with Vertical Guidance (APV) to replace Non-Precision Approaches (NPAs).
- The potential for SBAS derived positions to be used as a source for Automatic Dependent Surveillance (ADS).

4.4 Overcoming limitations of conventional navigation systems in the AFI region

Conventional navigation aids are those such as VOR, DME, NDB and ILS. Installation and maintenance of these aids is difficult in large parts of the AFI region, either due to their remote locations or it being impossible to site them in oceanic regions [7]. Reference [7] cites the ICAO navigation database as showing that 12% of aids are unserviceable and that an additional 18% are required to meet current plans. In order to implement the additional 18% of navaids in AFI region, an initial investment of about €28M based on costs from [15]. Each navaid type has been assumed to increase by the required 18%.

The figures for costs obtained from [15] don't incorporate inflation, as inflation would also then need to be applied to the benefits and thus have no effect on the final outcome. Also, it is very difficult at present to gauge the effect of inflation on navaids since more accurate information on current costs would be required.

Conventional navigation aids are also less dense in the AFI region, as the table below shows [4]:

	DME	VOR	NDB	Locator	ILS CAT I	ILS CAT II	ILS CAT III
Enroute	109	96	150	182	0	0	0
Approach	86	125	62	5	96	20	1
Total	195	221	212	187	96	20	1
Additional Navaids required to meet ICAO standards	35	40	38	34	17	4	0

Table 4: The number of navigation aids in the AFI region

A report from the UK CAA flight operations department [10] indicates a recent occurrence illustrating the problems with navaid reliability and the potential role of SBAS to cope with these situations It describes a potential CFIT incidence in an African State which suggests that an erroneous signal from a VOR caused an error in the position computed by the Flight Management Guidance System (FMGS). The aircraft did not have GPS and as a result the position error was not detected. The aircraft was 2.6 NM North of its intended position and cleared terrain by 56 ft. One of the recommendations was as follows:

- "Operators should endeavour to use aircraft with GPS on routes that involve long sectors both over water and terrain that terminate in remote areas served with few navigation aids."

Many of the navigation requirements can be met with GPS alone, so at first sight there may appear little benefit of SBAS. However, SBAS provides additional integrity over GPS while offering the benefits of centralised management and maintenance. These will provide an extra layer of assurance to those States that make use of SBAS.

4.5 Increased safety

Conventional navigation aids are also subject to integrity requirements, although historically these have not been defined. For example, DME and VORs can give false positions, outside of their specified accuracies, without any warning. The above mentioned incident is a good example and with the future introduction of stringent RNP navigation, the integrity of all navigation aids will be more critical.

Current operational RNAV requirements can mostly be met by GPS with RAIM, although some very high RNP accuracies would benefit from SBAS. As noted in the previous section, however, SBAS provides an additional layer of safety over conventional GPS. SBAS systems may even need less back-ups than GPS on its own. For example, Special Federal Aviation Regulation 97 provides authorization for trained pilots to use SBAS receivers (TSO 145/146 certified) as the sole means for en route navigation in Alaska.

SBAS augmentation of GPS provides increased integrity and more availability over GPS augmented with RAIM. The probability of SBAS not detecting a failure is 10^{-7} compared to 10^{-3} for GPS with RAIM.

The provision of vertical guidance during approach when ILS is not available is a key safety benefit. As previously discussed, APV Baro-VNAV provides a similar benefit here to APV SBAS, although SBAS may better suit the African continent than Baro-VNAV for the following reasons:

- SBAS does not require an accurate pressure reading from the airfield with a calibrated altimeter. This simplifies requirements on the airfield operations.

❖ APV supported by Baro-VNAV raise safety issues because of the absence of independent geometric vertical guidance [8]. Reference [8] also refers to ICAO PANS OPS, which recommends use of a supplementary means to mitigate the impact on safety, of any mistakes (from ground or on-board) in setting barometric altitude. The supplementary means includes using all other types of ICAO approaches (ILS, MLS, GBAS, SBAS, etc.) with vertical guidance, or a cross check between the approach slope and the barometric altitude or height on a specific reference point.

Another issue is that of system redundancy. It seems fair to assume that older aircraft are less likely to have multiple high integrity navigation sources: INS, GPS plus RAIM etc. The age profile of the African fleet may therefore imply greater benefits from SBAS as many aircraft may not already be equipped with triple redundant INS for example. Figure 4 compares the average age of the African and European fleets to illustrate this point.

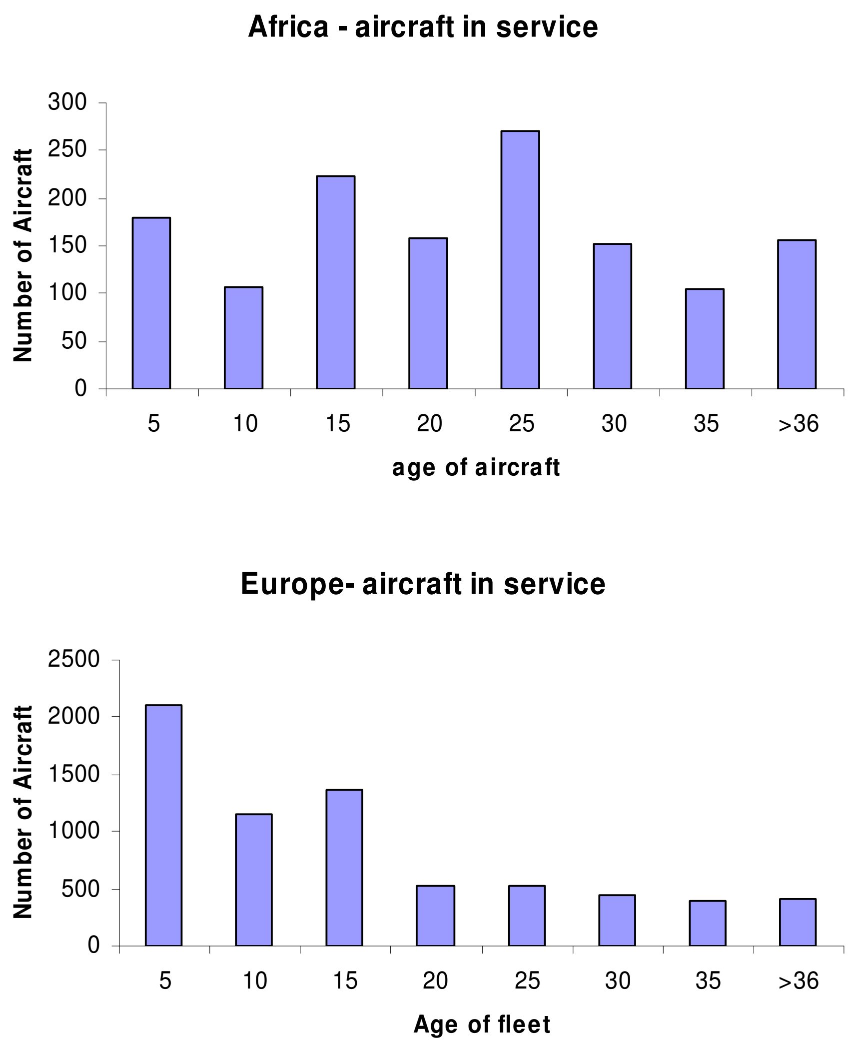

Figure 4: Comparison of aircraft ages between Africa and Europe (source: Airclaims)

4.6 Potential for APVs to replace NPAs

APV is an approach where the RNAV system provides lateral and vertical guidance. APV is a relatively new ICAO term and it is neither an NPA nor a precision approach. Two types of APV have been defined by ICAO: APV I and APV II. APV I uses GPS to provide the lateral guidance and either SBAS or barometric input ('Baro-VNAV') for vertical guidance. APV II has lower minima and requires SBAS inputs for both vertical and lateral guidance. The table below summaries the different criteria for NPA, APV I and APV II [11]. It also shows the criteria for Category I ILS. Only APV I will be supported by EGNOS for the AFI region and this report focuses on that option.

Operation	Accuracy (m, 95%)		Integrity	Alert Limit (m)		Time to alert (s)
	Horizontal	Vertical		Horizontal	Vertical	
NPA	220		$1-(1x10^{-7})$ per hour	555		10
APV I	20	20	$1-(2x10^{-7})$ per approach	40	50	10
APV II	16	8	$1-(2x10^{-7})$ per approach	40	20	6
CAT I	16	4 – 6	$1-(2x10^{-7})$ per approach	40	10 – 15	6

Operation	Time to alert (s)	Continuity	Availability
NPA	10	$1-10^{-5}$ per hour	0.99 to 0.99999
APV I	10	$1-8*10^{-6}$ per 15 s	0.99 to 0.99999
APV II	6	$1-8*10^{-6}$ per 15 s	0.99 to 0.99999
CAT I	6	$1-8*10^{-6}$ per 15 s	0.99 to 0.99999

Table 5: Approach criteria

For commercial operations, ILS is usually used in preference to NPAs. But in some cases, the sophistication of an ILS is not required and an APV approach would be sufficient since it provides an ILS-like approach. Therefore APV approaches (both APV I and APV Baro-VNAV) may in some cases be an alternative to ILS.

It is relevant to consider the proportion of time that meteorological conditions require precision or non precision approaches. This was studied in reference [3] and is summarised as follows:

- Category 1 ILS was suitable across the AFI region for approximately 99% of weather conditions (decision height of 200ft and runway visual range of 0.5 miles).
- APV I (defined in the study with a decision height of 500 ft and runway visual range of 0.75 miles), was suitable for between 95% and 98% of weather conditions.
- Figures for NPA were not given explicitly in reference [3]; however, the difference between NPA and APV I conditions was calculated. The study concluded that APV I conditions would cover between 2 and 3.5% of the conditions that would be unsuitable for NPA. Put another way, if an aerodrome supported non precision approach rather than APV I, there would be a 2-3.5% probability that the visibility conditions would be unsuitable for landing and the aircraft would have to divert.

4.7 Potential for ISA to support automatic dependent surveillance

Improved situational awareness and increased procedural airspace can be achieved through SBAS derived positions for Automatic Dependent Surveillance (ADS) There are two types of ADS: ADS-C (contract) and ADS-B (broadcast). They both transmit an aircraft's position at regular intervals. ADS-B also transmits its position to aircraft in range; the idea being that aircraft can 'see' each other.

ADS-C is operational in certain regions, particularly oceanic, where other sources of surveillance are not practical. The position is derived from on-board navigation systems and, due to various errors, will support only limited separation standards (30Nm at most). Recent work [12] has confirmed it is feasible to use ADS to support 3Nm and 5Nm separations, assuming GPS positioning. Reference [12] assumed a high integrity navigation source was required, but did not go as far as identifying performance requirements for the positioning source.

The relevance of ADS to the AFI region is as follows:

- ❖ The region has portions of airspace that are not covered by radar and are therefore under 'procedural' control. In such conditions, aircraft periodically report their position to ATC, so that the controller builds up a picture of traffic. The separation minima applied ensures that it is very unlikely that aircraft are in conflict. The advantages of ADS are improved safety and more efficient (direct) routes.
- ❖ ADS-B may provide lower cost surveillance coverage than conventional radar. For example, there is particular interest in ADS-B for parts of Australia, albeit a minimal form of ADS-B which takes advantage of new Mode S transponders.

The above benefits of ADS need to be considered alongside the costs of equipage, which may be quite large.

GPS with RAIM can meet the requirements for ADS as it is presently defined. However, using EGNOS will add to the integrity of the surveillance information and may therefore encourage take-up of ADS.

4.8 Quantifying the benefits for aviation

The preceding discussion identified broadly where the benefits of ISA may arise. The following sections quantify some of these as follows:

- ❖ improvements in safety;
- ❖ cost savings through phasing out of ground based navaids;
- ❖ cost savings by using APV.

The following paragraphs discuss these benefits in more detail.

4.9 Improvements in safety

Limited navigation performance could lead to Controlled Flight in to Terrain (CFIT) occurrences, as illustrated by the incident reported in [10] that is discussed earlier. Hence there is a safety argument for using APV approach procedures and SBAS is one possible way of achieving this through APV I approaches.

Note that APV Baro-VNAV is an alternative solution that will suit some aircraft. Like APV I, APV Baro-VNAV also overcomes many of the disadvantages of NPA although it may have higher minima than APV I and it has been argued to be marginally less safe than APV I because it requires manual barometric altimeter setting. Different aircraft may benefit from APV SBAS and APV Baro-VNAV depending on their current equipment and upgrade options.

Specifically, modern aircraft with certified VNAV systems will in many cases already be capable of APV Baro-VNAV. However, aircraft without certified VNAV systems may find it easier to upgrade to APV I than APV Baro-VNAV. This is because upgrading the GPS receiver to include SBAS may be less work than upgrading the VNAV system and its interface to the FMS. The specifics will vary between aircraft types.

In 2003, there were 7 fatal accidents[9] that occurred in African territories. Of the accidents that occurred over African soil, 3 (42%) were as a result of CFIT. This compares to a total of 9 worldwide that year. CFIT related accidents accounted for 36% of worldwide total accidents in 2003[10].

Region	**2003**	**2002**	**2001**	**2000**	**1999**
Africa	7	10	4	9	9
Asia	2	11	44	8	12
Australia	1	0	0	0	3
Central America	1	0	2	4	2
Europe	5	7	10	5	7
North America	4	4	9	9	6
South America	5	5	5	1	6
Total	*25*	*37*	*74*	*36*	*45*

Table 6: Number of fatal airliner accidents per region

[9] Aviation Safety Network study, www.aviation-safety.net

[10] Airliner Accident Statistics 2003, by Harro Ranter, www.aviation-safety.net; http://aviation-safety.net/pubs/2003.pdf

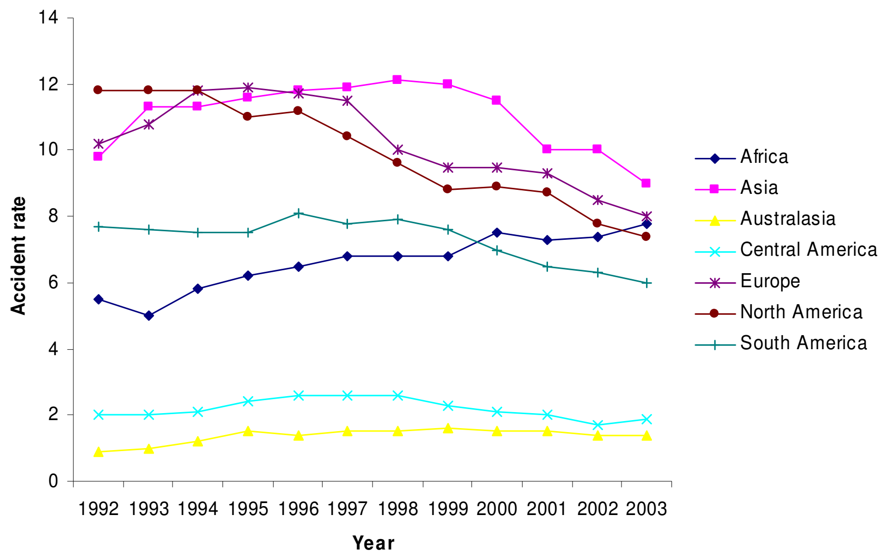

Figure 5: Moving 10 year average graph of accident[11]

As shown in Figure 5, whilst the accidents rates of all the other regions have been decreasing or staying at a constant rate, Africa has been increasing steadily over the past 10 years.

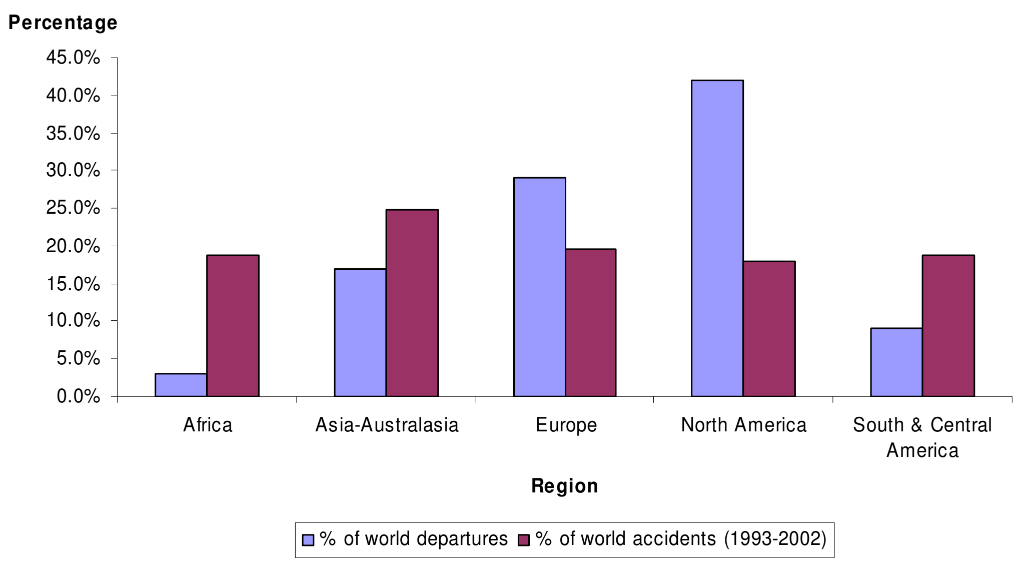

Figure 6: Comparison of world departures to accident rate

What is most noticeable about Figure 6 is that although Africa accounts only for 3% of world departures, it makes up 19% of world accidents.

[11] Airliner Accident Statistics 2003, by Harro Ranter, www.aviation-safety.net; http://aviation-safety.net/pubs/2003.pdf

Africa also accounts for 3% of the world aircraft movements[12], and there were 1.7M movements in 2003. This means that there were 7 accidents per 1.7M movements in Africa, or 0.25 accidents per million African movements for period in 2003. This compares to 0.1 per million movements worldwide.

The safety benefits of ISA could be realised from a reduction in the number of aircraft landing accidents. This results from the availability of SBAS at runways that are currently not equipped with an operational ILS. Most of the benefits therefore, would result from the use of SBAS APV I approaches at airports without an ILS on any runway. ISA can therefore be seen as a cost effective solution to achieving higher safety standards in the AFI region.

The WAAS CBA [13] compares accident rates for NPA and precision approaches, concluding that there is one avoidable accident for every 116,000 NPA in the case of air carriers. According to ACI, in 2004, there were a total of 1,757,060 aircraft movements in Africa, with 878,530 arrivals. This report makes the assumption that the percentage of approaches that are NPAs is in the range of 10-30% although we currently have no evidence for this figure. Extrapolating the findings of the WAAS CBA implies that between 0.76 and 2.27 accidents per year related to NPAs could be avoided. In order to quantify the estimated safety benefits in financial terms we have used standard hull-loss and statistical value of life figures.

It should be noted that most NPAs will be flown at airfields without precision approach facilities. Thus some accidents could be due to the airfield environment, and cannot therefore be avoided by new approaches alone. Similarly, other safety problems exist in the AFI region other than CFIT, such as poor maintenance or lack of compliance with operational standards. Centralised management and maintenance of navigation facilities would help address some of these.

4.10 Cost savings through reducing ground-based navaids

This section examines the benefits of reducing ground-based navaids. We have assumed that some navaids can be decommissioned as follows:

- En-route navaids can be reduced as GNSS becomes more widely deployed. As GNSS and RNAV are more widely used, ground based navaids will probably be thinned to keep a “backbone” network for reversionary purposes. This benefit is not necessarily exclusive to SBAS and it may be possible with GPS alone. However, SBAS provides States with centralised monitoring of the GPS service which we have assumed will accelerate the decommissioning of navaids. We have assumed that DMEs are retained much longer than VOR/NDBs as they provide an RNAV capability until a ‘sole service’ GNSS environment is possible.
- Airport navaids for NPA may be phased out as APV becomes widely deployed. This strategy will require both APV SBAS and APV Baro-VNAV to be deployed simultaneously.
- Some ILS may be decommissioned as APV becomes widely deployed. In some cases, ILS was only installed as NPA was considered insufficient – not because a precision approach capability was required. AFI representatives have stated that APV would be a suitable alternative to ILS in some cases.

[12] Airports Council International, ACI Study, 2001.

Reference [4] has looked to determine the benefits of EGNOS as a phasing out of NDB/L, VOR and DME. These were estimated to be $242M (€223M[13]) over the period 2000 – 2020. This study did not consider any benefit of ILS rationalisation through the use of APV.

This study undertook an updated analysis using the following assumptions:

- The number and operational state navaids in operation in the AFI region is based on [3] and Table 4.
- The cost of the navaids is based on [14]. Their operating and renewal costs is defined in [17].
- The operational life of a navaid is 15 years.
- From 2015 the VORs and NDBs are not replaced when they reach the end of their operational lives. This leads to a slow thinning out of the ground network, with its total removal around 2030.
- From 2015, only about half of the DMEs are replaced when they reach the end of their operational lives. This leads to a much slower thinning of the DME network, with its total removal around 2045. An alternative strategy would be to continue replacing DMEs to a later date (eg 2020) to maintain a full RNAV capability and then decommission them more quickly. We have assumed that this strategy would yield a similar financial result.
- From 2015, some ILS are not replaced. We have assumed that about 50% of the ILS could be decommissioned if APV were available to all aircraft.

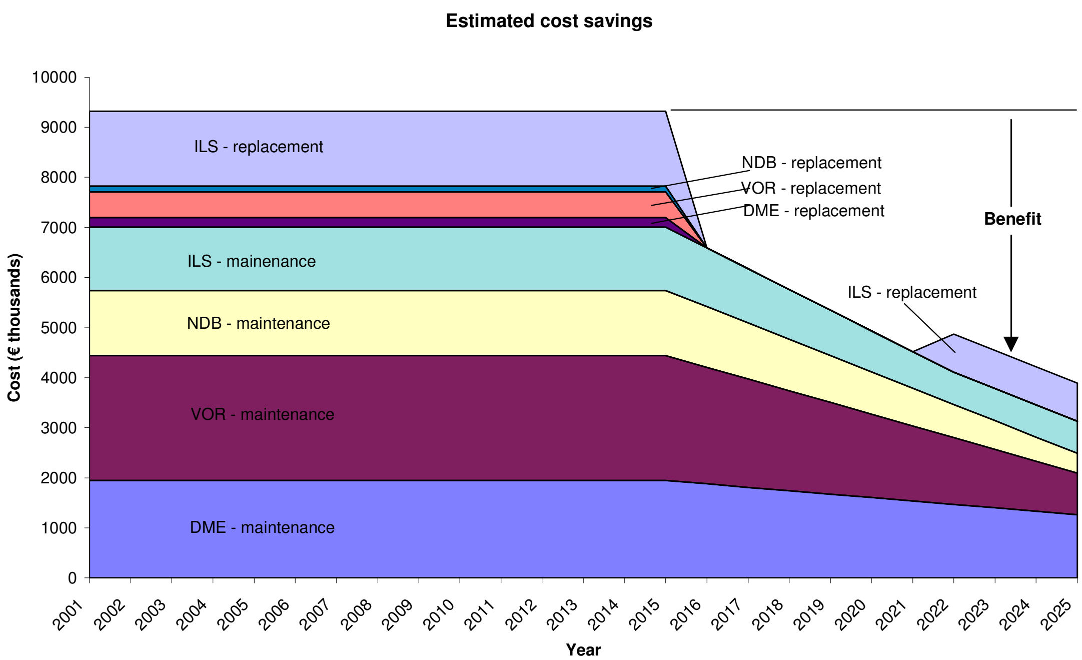

Figure 7: Navaids cost to 2025

The figure above shows how the navaid costs slowly reduce after 2015. The costs saved from this equate to the potential benefits to be achieved by the non-replacement of navaids. The discontinuity seen on the right of the graph is as a result of some of the ILS being retained. At this stage, half of

[13] Based on average annual exchange rate of $1 = €0.92318254 for the year 2000.

the ILS have already been decommissioned through non-replacement and so to maintain the current numbers, the existing ILS are now replaced once they reach the end of their operational lifetime.

4.11 Cost savings by using APV

Using APVs instead of NPAs will have a safety benefit by reducing CFIT, but it will also bring cost savings as discussed below.

Reference [4] valued the operational benefits of avoiding disruption as €41M NPV (discounted at a rate of 8%) for the period 2005 – 2020. This was based on a composite cost of disruption of €1638 per flight; assuming either delay, diversion or cancellation. These benefits are gained by assuming that APV approaches will have lower minima than NPAs and therefore will be possible in conditions when the NPAs would not be possible. Based on this, figures have been extrapolated for a further 5 years, to extend to the timescale of this study.

APVs can also reduce the incidence of circling approaches, where the aircraft must overfly the airfield before making the approach. Circling approaches may be required when aircraft are not equipped with FMS/RNAV systems. The benefit in these cases is that the RNAV capabilities offered by the SBAS equipment allow the aircraft to navigate to the start of the approach without overflying the airfield. However, quantification of this benefit is unlikely to yield significant value because:

- Circling approaches are sometimes required anyway to, eg, check the runway is clear prior to landing.
- Aircraft that are equipped with FMS or RNAV systems can usually avoid circling approaches anyway. Aircraft that are not FMS or RNAV equipped can anyway avoid circling approaches if ATC radar is available to vector them to the airfield.

APVs also offer a benefit of reduced cockpit workload compared to conventional NPAs, which is also a result of the improved situational awareness and the availability of continuous descent navigation guidance during the approach. The continuous descent can also save money compared to a stepped down approach which is sometimes applied during conventional NPAs.

Finally, APVs can help deliver some of the benefits of FMS or RNAV approaches since an integrated SBAS receiver could be a cheaper way to get the benefits of these approaches to aircraft that are not already FMS/RNAV equipped. This is likely to be a fairly small number of commercial aircraft but is valuable to those aircraft that it affects.

4.12 Summary of benefits

The benefits discussed in the preceding paragraphs are summarised in this section.

The table and figure below summarise the potential benefits achievable from the reduction of accident rates, avoided diversion rates and the non-replacement of navaids. All figures are Net Present Values (NPVs) discounted at 8%.

Year	Annual Cost savings due to reductions in			Total (€ M)
	Accidents rates (€ M)	Diversions/delays/disruptions (€ M)	Non-replacement of navaids (€ M)	
2005	0.4	1.0	0.0	1.4
2006	0.9	3.0	0.0	3.9
2007	1.4	5.0	0.0	6.4
2008	2.0	6.0	0.0	8.0
2009	2.6	9.0	0.0	11.6
2010	3.2	11.0	0.0	14.2
2011	3.9	13.0	0.0	16.9
2012	4.6	16.0	0.0	20.6
2013	5.4	18.0	0.0	23.4
2014	6.2	21.0	0.0	27.2
2015	6.4	22.0	0.0	28.4
2016	6.7	23.0	2.7	29.7
2017	6.9	24.0	3.1	30.9
2018	7.2	25.0	3.6	32.2
2019	7.5	26.0	4.0	33.5
2020	7.8	27.0	4.4	34.8
2021	8.1	28.0	4.8	36.1
2022	8.3	29.0	4.5	37.3
2023	8.6	30.0	4.8	38.6
2024	8.9	31.0	5.1	39.9
2025	9.2	32.0	5.4	41.2

Table 7: Annual benefits of ISA for Aviation

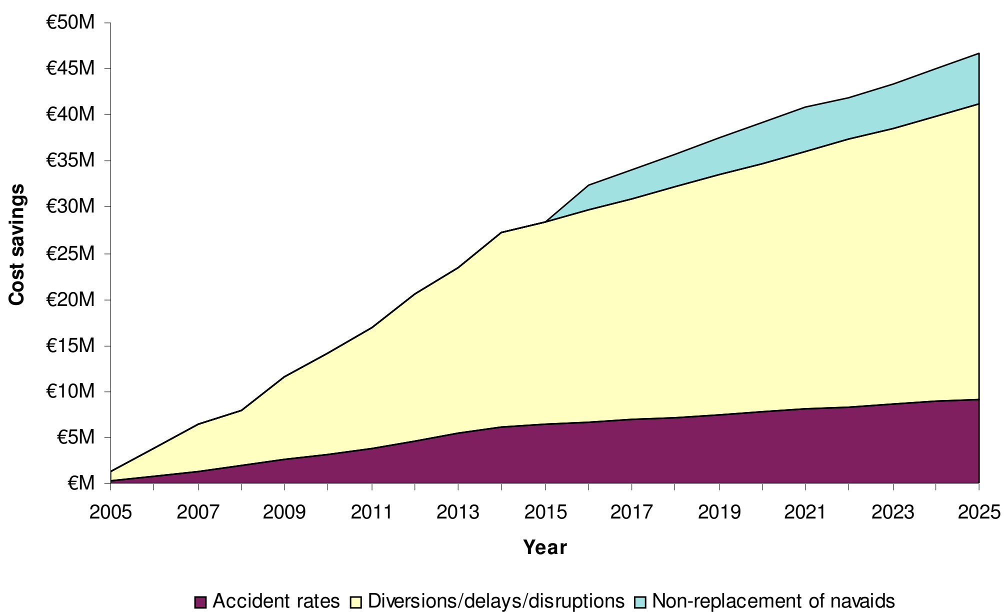

Figure 8: Annual benefits of ISA for aviation

The cumulative cost saving is €516M by the year 2025.

5. Cost to user community

5.1 Overview

This section of the document deals with the cost in equipping the African fleet with SBAS capability. The cost of operating and financing the necessary ground infrastructure for SBAS is also considered at the end of the section. A full cost analysis is not inside the scope of the study, but this section will provide a baseline for further costing analysis.

The methodology comprises the following:

- analysing the current African fleet (size, characteristics, etc.);
- assessing the processes and costs for upgrading;
- estimating the future evolution of the fleet;
- calculating the overall cost of upgrade, assuming a realistic timescale.

This section will serve to:

- provide a guide value for the implementation cost of SBAS functionality onboard the African fleet;
- educate users and decision makers and provide a starting point for subsequent decisions at a national and international level;
- provide potential input for a full investigation into the business case for EGNOS in the AFI region.

Note, that at the time of writing, Boeing and Airbus have indicated they do not have plans to begin manufacturing aircraft with SBAS capabilities. However this report assumes that new aircraft will nevertheless become available with SBAS capability from 2010. .

5.2 Current African fleet

To calculate the current African fleet size, we have used the Airclaims database[14], a global directory containing extensive information on all aircraft registered within a particular region. This includes information relating to aircraft status (service/in store), type, age, size, usage, etc and was used in investigating Africa's fleet characteristics in verifying our assumptions.

For the purpose of this study, we have considered aircraft which belong to the following three categories:

- Passenger;
- Freight or cargo;
- Combi/mixed (passenger and/or cargo).

[14] http://www.airclaims.co.uk/Home/About.aspx.

The number of aircraft can then be calculated directly from the Airclaims database by analysing those only registered in the AFI region. We have assumed that European aircraft will be driven by European pressures when equipping with SBAS, and will not equip just to gain benefits in Africa. Most European aircraft will have APV Baro-VNAV capability anyway and therefore will not need to equip with SBAS to fly APV approaches.

Figure 9 below shows that the majority of aircraft which are 30 years or less are in service, whereas for those greater than 30 years, there is a much larger proportion in storage. Since most aircraft at this age are reaching the end of their operable lifetime[15] we estimate the fleet size as being those aircraft only 'In service'. This gives the current fleet size as 1,350.

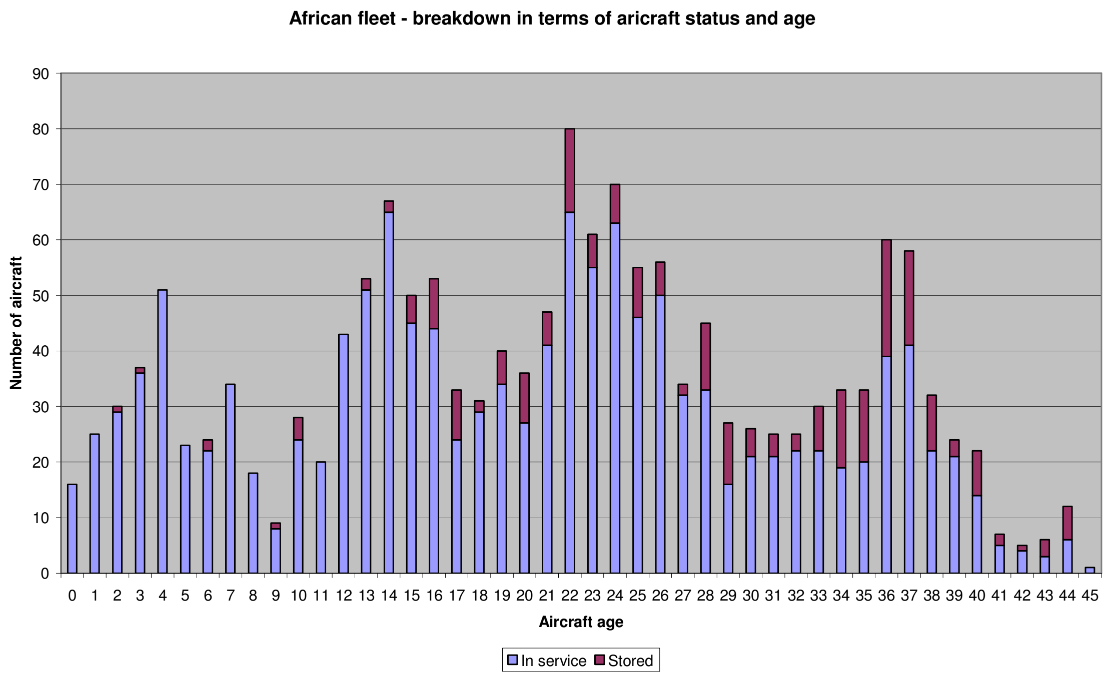

Figure 9: Aircraft status versus age

As we will see in Section 5.3 our costs per aircraft will be based on aircraft type. The aircraft are grouped into the following categories[16]:

- T1 - light single engine, pressurised aircraft (piston or turboprop);
- T2 - light multi-engine pressurised aircraft (piston or turboprop);
- T3 - large turboprop;
- J1 - light business jet;
- J2 - midsize business jet;

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[15] Note that generally aircraft in storage cannot be omitted. They may be awaiting repairs, spare parts, new ownership transport or simply over-meeting requirements and sot cannot be assumed to be permanently out of service.

[16] http://www.icao.int/anb/ais/8643/index.cfm.

❖ J3 - commercial jets and large business jets[17].

The current age distribution of the fleet is shown below.

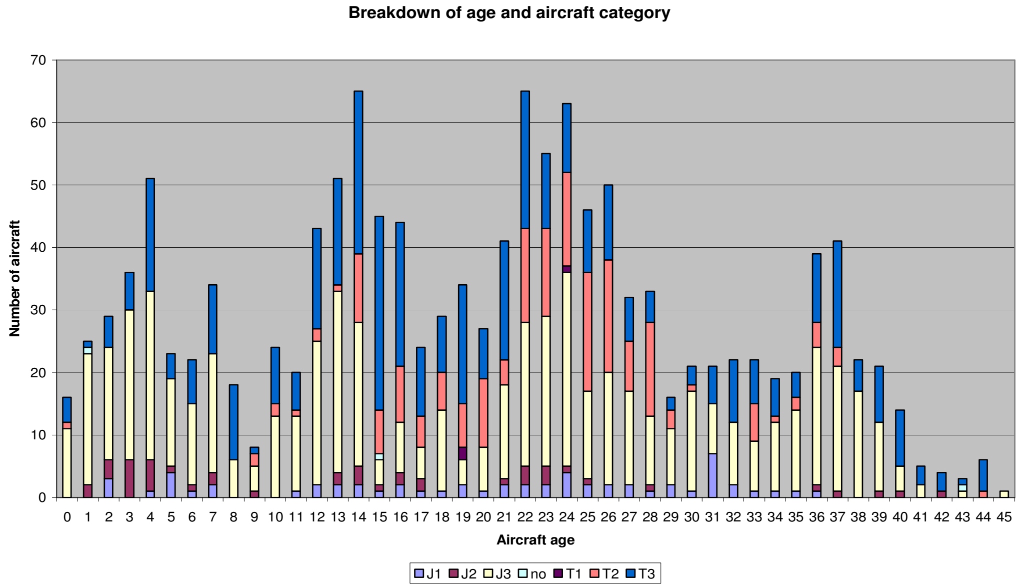

Figure 10: Fleet category profile

Examining the fleet breakdown, we see that almost half the fleet consists of J3 aircraft. With complicated integration requirements these will contribute significantly to the cost of equipage.

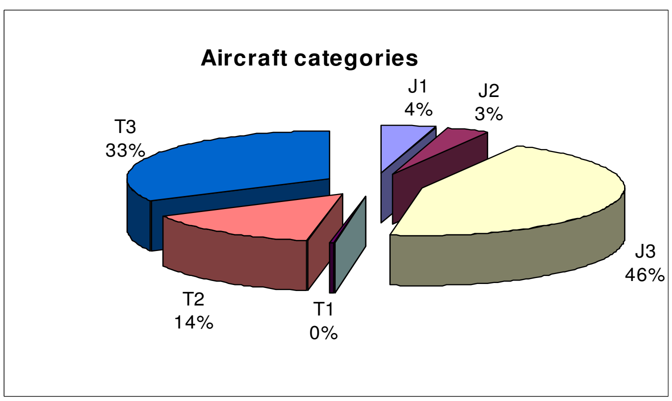

Figure 11: Fleet category breakdown

In our model, we assume this to remain constant through to 2025. Even with industry growth, while new, larger aircraft are acquired, a corresponding number of smaller aircraft will be maintained to service new routes.

[17] 'no' is for aircraft with no known category match. 0.02% of aircraft registered were of unknown type and were unassigned.

5.3 System costs

Here we aim to provide an estimate of the cost per aircraft of an SBAS upgrade. This will depend on the aircraft type as well as whether the upgrade is a retrofit or a forward fit. The inputs and assumptions in deriving these system costs are based on and have been validated from a previous study [18]. They incorporate current market values as well as input from industry consultation.

The processes and costs involved can be classified into the following six categories:

- cost of SBAS receiver;
- integration into FMS/CDI, etc;
- installation;
- crew training;
- documentation (STC/SB);
- certification.

Equipment installation, integration, etc. will be more expensive on larger aircraft and so it is important to consider the fleet profile in the overall costing. Table 10 and 11 presents these system costs for a retrofit and a forward fit respectively according to each category of aircraft categories and their rationale is given below. Entries marked by an asterisk '*' indicate double equipage for redundancy.

Cost of retrofit per aircraft						
Cost values	**J1**	**J2**	**J3**	**T1**	**T2**	**T3**
SBAS receiver	€ 20,000	€ 40,000*	€ 40,000*	€ 14,000	€ 14,000	€ 28,000*
Integration	€ 50,000	€ 50,000	€ 50,000	€ 8,000	€ 8,000	€ 50,000
Installation	€ 6,000	€ 12,000	€ 12,000	€ 3,450	€ 3,450	€ 12,000
Crew training	€ 3,000	€ 3,000	€ 3,000	€ 3,000	€ 3,000	€ 3,000
Documentation	€ 10,000	€ 30,000	€ 30,000	€ 2,000	€ 2,000	€ 30,000
Certification	€ 700	€ 700	€ 700	€ 700	€ 700	€ 700
Total cost	**€ 89,700**	**€ 135,700**	**€ 135,700**	**€ 31,150**	**€ 31,150**	**€ 123,700**

Table 8: Retrofit costs

We have assumed that forward fit costs will be included in the cost of the new aircraft. This is because the SBAS capability will be an extension to the existing GPS systems. Therefore the forward fitting of an aircraft with SBAS will only incur the cost of crew training.

Cost of forward fit per aircraft						
Cost values	**J1**	**J2**	**J3**	**T1**	**T2**	**T3**
Crew training	€ 3,000	€ 3,000	€ 3,000	€ 3,000	€ 3,000	€ 3,000
Total cost	**€ 3,000**	**€ 3,000**	**€ 3,000**	**€ 3,000**	**€ 3,000**	**€ 3,000**

Table 9: Forward fit costs

<u>Receiver</u>
This includes the cost of SBAS receiver transponder, antenna, cables and harness.

<u>Integration</u>

(CDI) integration is required by all aircraft categories. However integration into the Flight Management System (FMS) is only necessary for larger aircraft and assumes revised software for an existing FMS.

Installation

The installation cost shown represents the total labour cost incurred, based upon a total of five man days at an hourly rate of €75 and was provided by AZB[17]. We have assumed that unscheduled downtime for the aircraft will not be required.

Crew training

These costs include training necessary to familiarise crew with the new equipment and procedures. It does not include any training necessary as a result of introducing SBAS. They are based upon an assumption of a half-day training course for 12 staff at €250 per person.

Documentation

The cost for documentation includes airworthiness certificate, updating flight manuals, writing diagrams and flight procedures. This has been estimated upon information provided by Aerodata and assumes that the equipment has already been STC-approved by the installer.

Certification

The certification cost represents the charge incurred from the relevant certification authority to verify the installation. It is assumed that the aircraft owner/operator will seek certification through an STC (Supplementary Type Certificate), issued through a third party to the aircraft operator, and therefore no additional cost is incurred due to development of STC and other certification material since it is assumed that it will be absorbed into equipment and installation costs. The cost here is based upon data provided by UK CAA.

Variation of these costs assumptions is given in the sensitivity analysis.

5.4 Fleet evolution

This section of the document focuses on addressing the future evolution of the African fleet from 2005 to 2025. The analysis is based upon two key inputs:

- growth figures for the aviation industry, inferring fleet evolution on a supply-demand basis;
- forecasts of Africa's Real GDP (Gross Domestic Product, adjusted for inflation) which is used as an indication of a nation's economic activity.

As a whole, the African aviation industry is expecting positive growth. According to figures announced by the Secretary General of the ACI[18], aviation will see an annual increase of 3.9% through to 2010. Studies undertaken as part of work for the European Union [15] predict the movement rate in the AFI region to show a steady and consistent growth up to 2012 and possibly beyond.

18 The Namibia Economist – 15 Nov, 2002.

Furthermore, an examination of figures for Africa's Real GDP adjusted for inflation) reveals that it has remained at a constant level of 2% of the world share since 1970. It is forecast to remain at this level right through till 2020[19] [16]. This analysis reinforces the above findings of steady growth.

Whilst the ACI figures only consider the market growth until 2012, this study extrapolates the fleet size to 2025. We have assumed that the constant annual growth of 3.9% continues through to this point, of which the GDP analysis is in support of. Secondly, in view of the global market such steady growth is likely to continue for some time. Africa has proved to exhibit similar to trends to both Europe and to the US in the past and this is likely to continue.

In terms of SBAS equipage, we assume that by 2015 all aircraft will be equipped with either SBAS or Baro-VNAV enabling the entire fleet to operate using APV. This is consistent with previous studies and

5.5 Total fleet cost

With inputs on the cost per aircraft and future fleet evolution from the previous sections we can now estimate the overall cost for equipage. Presented below is a chart illustrating the individual cost contributions from retrofitting and forward-fitting together with the assumed equipage profile.

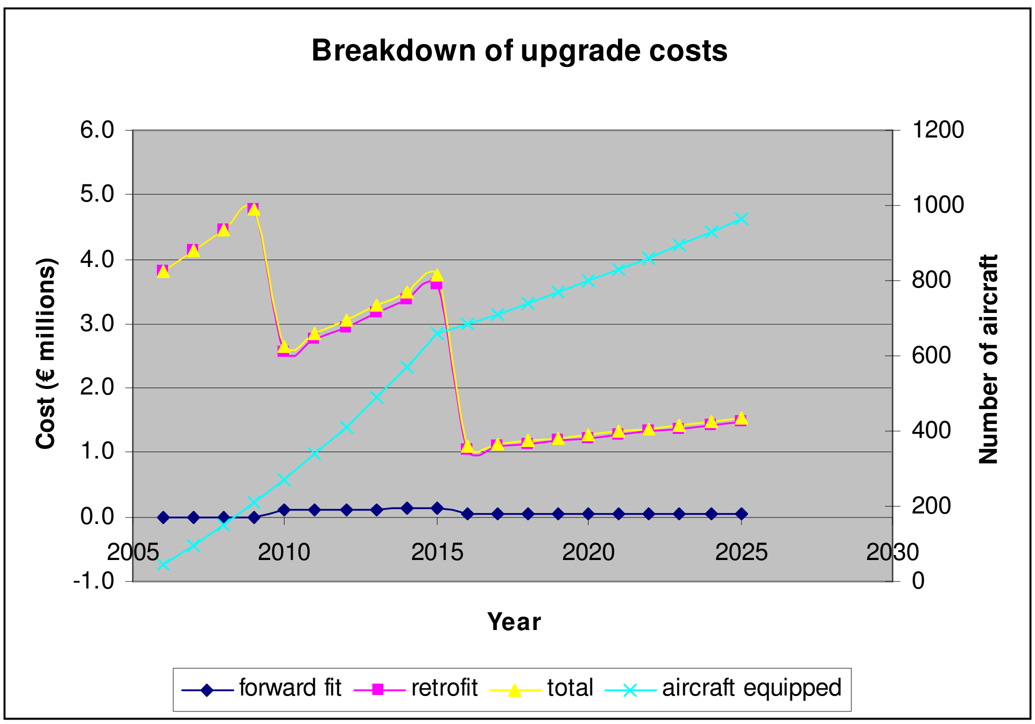

Figure 14: Upgrade costs

We have assumed that retrofitting is the dominant cost and that is shown here.

[19] http://www.eia.doe.gov/emeu/cabs/archives/africa/africa.html#economics%20and%20demographics, Official statistics from the Energy Information Administration.

The total cost profile has two main features. The first step-down seen at 2010 marks the period from which it is assumed manufacturers begin provisioning their aircraft with SBAS capability. It is from this point on that forward fitting becomes an option. The impact on overall cost is insignificant.

The second step-down feature marks the time at which the entire fleet becomes APV capable. From this point on, retrofitting is no longer required and so the costs drop dramatically. This is also mirrored by the change in slope in the 'aircraft equipped' curve, which slows down from 2015.

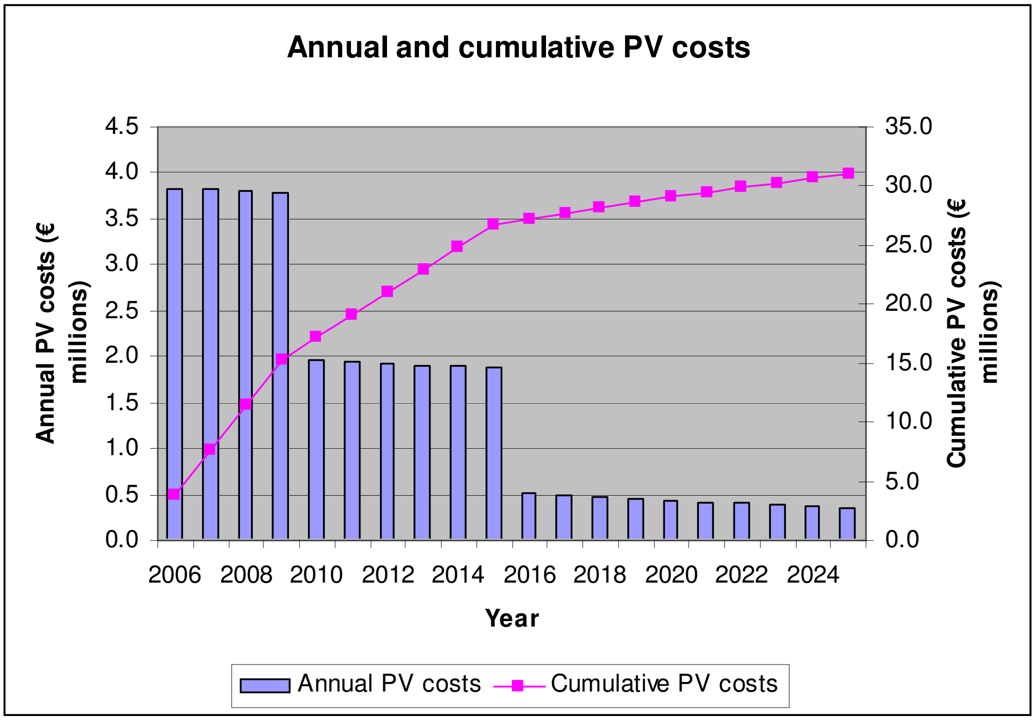

Figure 15: Annual and cumulative NPV costs

In the above diagram the costs have been discounted at a rate of 8% per year to give a Net Present Value (NPV). Summing over the 20 years, the cumulative cost to upgrade the fleet amounts to an estimated total of €31 million NPV.

5.6 Cost of SBAS ground infrastructure

Four scenarios have been considered, tabulated below, to account for the cost of the necessary ground-side infrastructure. This approach is typical of the necessary repayment structure and assumes:

- an investment cost of €50M and of €30M over 10 years, with 10% per year operating costs;
- interest rates of 6% and 8%.

The average implementing, operating and financing costs are shown in the table below. The payment period is assumed to be 10 years at current prices. It shows that total operating and financing costs are likely to total between NPV €7 - 13M per year for the 10 years that finance is re-paid. After that, operating costs reduce to €3 - 5M. Total implementing, operating and financing costs are therefore in the range €100 - 180M over 20 years.

Interest Rate	6%		8%	
Amount to be financed (€M)	30	50	30	50
Average annual payment (finance costs) – (€M)	4.1	6.8	4.5	7.5
Operating costs (10%) – (€M)	3	5	3	5
Total Annual Payment/Revenue – (€M)	**7.1**	**11.8**	**7.5**	**12.5**

Table 10: Financing repayment summary (10 year repayment period)

Based upon the strong interest of several AFI region ANSPs, there is a strong case for the implementation and operating costs of ISA to form the basis of a revenue scheme; although further cost sharing with other transport modes should be explored. The figures shown at the foot of Table 8 should therefore be taken as the current baseline for future annual revenue estimates. This statement assumes that the overall benefits can be shown to outweigh the costs.

Any approach to cost recovery is likely to be more successful through a limited number of service providers and to take advantage of existing revenue schemes. For example, based on airport movement figures from 2000 for the AFI, 8 airports from 7 different countries or territories make up 50% of the total movements within the AFI region. Although historical, this data illustrates the fact that, which still holds true today.

A public subsidy would reduce financing costs accordingly and this could be used to encourage faster take-up.

6. Sensitivity analysis

This section examines the potential impact of some of our assumptions. There is no way to predict with 100% confidence definite values for some of the inputs however this section aims to quantify as such and help to provide limits to the degree for which cost figures could vary as a result.

6.1 Industry growth rate

We have assumed an industry growth rate of 3.9% per year throughout the study. Below is a graph depicting both alternate optimistic (4.9%) and pessimistic (2.9%) scenarios. The shift in the different cost profiles is clear.

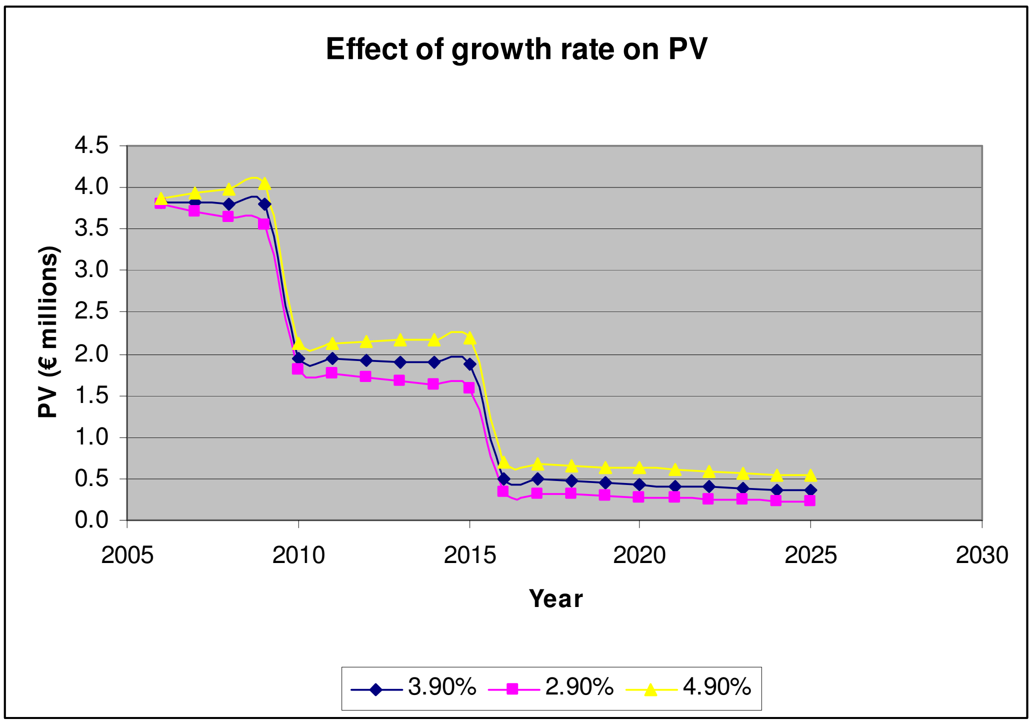

Figure 16: Effect of growth rate on NPV

The cumulative effect of this is such that a growth rate of 4.9% increases the total NPV cost by a margin of 12.5% at € 35 million. The reduction in total NPV cost given by a reduced growth rate of 2.9% rate is 10% at a value of € 27 million (as a result of the time value of money this will inherently be lower). The most likely future growth rate will be expected to lie close to, if just below, the 3.9% level.

6.2 SBAS uptake rate

Here we investigate the impact of the SBAS equipage rate on the cost. Our model has assumed an annual SBAS uptake of 10% of the non-APV Baro-VNAV aircraft, resulting in full equipage by the end of 2015. Below shows the variance between this and possible optimistic and pessimistic alternatives at reaching full SBAS equipage at 2017 and 2012 respectively.

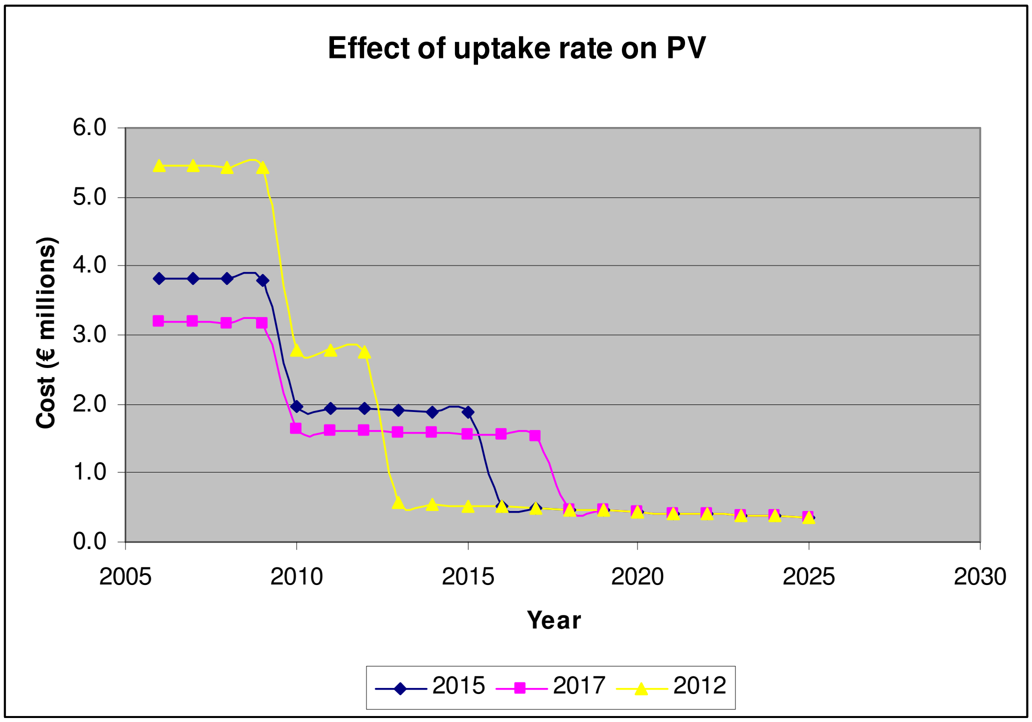

Figure 17: Effect of uptake rate on NPV

If the uptake rate is such that full APV capability occurs at 2017, then there is a decrease of 8% reducing the total NPV to €28 million. If the full APV capability is achieved at 2012 then the total NPV increases by 16% to €36 million Thus in reducing the rate at which fleets equip, the user community can achieve considerable cost-savings.

6.3 Fitting bias

The baseline model assumes equal bias in the action of equipping aircraft with SBAS, i.e. 50% of aircraft are retro-fitted and 50% of aircraft are forward-fitted. This section examines the impact of changes in that bias.

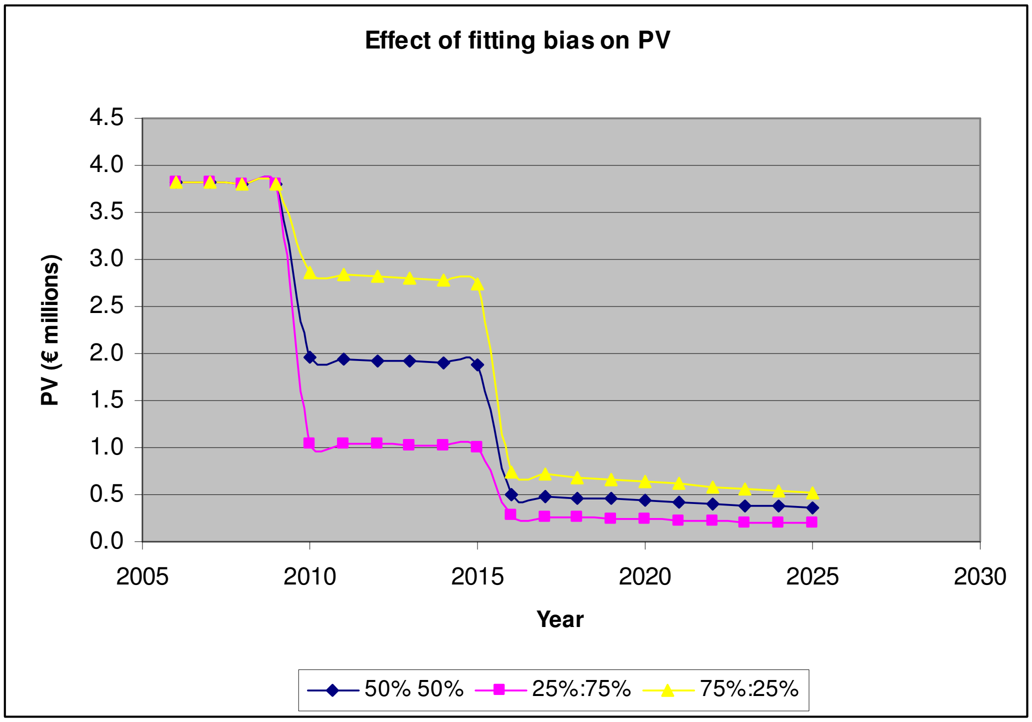

Figure 19: Effect of fitting bias on NPV

The diagram presented above shows a variance of ±25% from 2010, the assumed time at which forward fitting becomes an available option. The split is immediately apparent. The rate of change of annual cost remains the same however the effect on total NPV cost is seen to be of the order of ±24% resulting in a change of the order of €7 million to the total NPV.

This reinforces the fact that, despite clear benefits, the preference should be to delay equipage until forward fit kits become available, resulting in larger net benefits.

6.4 Equipage Costs

Here we investigate the sensitivity of the NPV cost to possible variation in the different equipage costs for both retrofit and forward fit across the aircraft categories. The figure below shows the resulting effect of a variation of ±25% on the baseline equipage costs. This results in a change of the order of €7 million to the total NPV cost

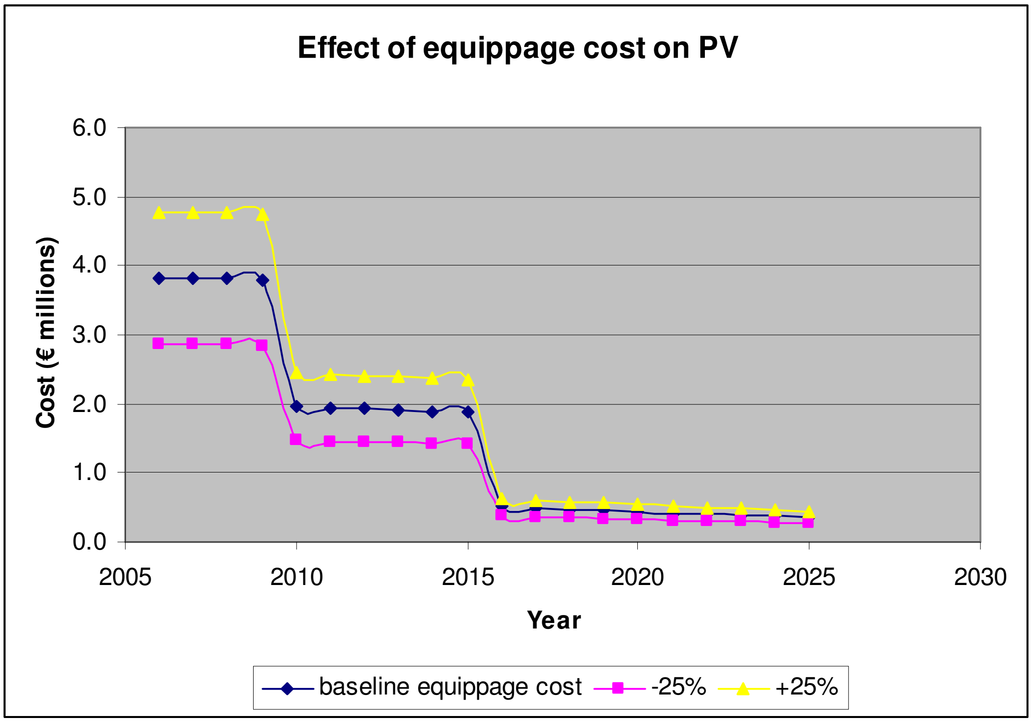

Figure 20: Effect of equipage costs on NPV

6.5 Summary

The table below summarises the impact of the various factors and assumptions effecting the baseline NPV of €31M:

Sensitivity	Baseline	Alternative scenarios			
Industry growth rate	3.9%	2.9%	-€4M	4.9%	+€4M
SBAS uptake rate	2015	2017	-€3M	2012	+€5M
Fitting bias	50:50	25:75	-€7M	75:25	+€7M
Equippage costs	Baseline	-25%	-€7M	+25%	+€7M

Table 11: Sensitivity analysis summary

As to be expected, with an increase in industry growth, the increase in the number of aircraft to meet this growth requires additional aircraft to be equipped, increasing the cost. The benefits however also increase.

The analysis also shows that if the point at which all SBAS capable aircraft are equipped is delayed, there is an opportunity to further increase the overall net benefit. As illustrated, decreasing the uptake rate so full equipage is achieved in 2017 results in a reduction of the total NPV to €29M.
However caution should be used here in that delaying this considerably would require the corresponding phasing out of navigational aids to be also delayed, as a large fraction of the fleet will still be dependant upon them.

A better strategy to reduce the overall cost is to maximise the number of aircraft forward-fitted. The cost of this relative to retrofitting is significantly lower, allowing for a significant cost saving to the airlines. Hence the earlier forward fit kits can become available the more beneficial it is for the whole industry.

We can also see the impact on the variation of these equipage costs. The model has assumed these remain constant for the timeline of the study. Naturally, however, these are likely to decrease as the technology improves and so we can expect a reduction of this order.

7. Strategic and macro-economic benefits

The African Civil Aviation Commission (AFCAC) supports the extension of EGNOS APV-I to the AFI region in the pursuit of current transport policy objectives under the EU-ACP Partnership Agreement [7]. This aims to improve the reliability and safety of maritime and air transport and ensure interoperability with EGNOS [15]. There is a particular focus on the safety of air navigation and the need to implement relevant international standards.

AFCAC cites the objectives of the Regional Indicative Programmes to show the consistency of EGNOS AFI in supporting global objectives. Under the 9th European Development Fund, regional co-operation with the four African beneficiary regions and the Indian Ocean focuses, among other things, on the following:

- strengthened regional economic integration;
- Improved regional cooperation in the field of sustainable development, including poverty alleviation, human resource development and environmental protection.

Through improvements in the quality, quantity, pertinence and timeliness of basic information available at appropriate scales from local to continental, the project will contribute to the implementation of an operational system. This operational system should in turn contribute to regional networking to transport safety and security (economic integration) and cost reduction.

AFCAC also point to the limitations of conventional communication, navigation and surveillance aids throughout Africa, where their availability and reliability are poor. Furthermore, there is little flexibility in current route structures leading to uneconomic routes. Although the project is widely supported by African countries, the benefits of EGNOS are more applicable to the regional than national level.

ISA is likely to encourage a number of regional cooperation actions in addition to the benefits discussed in the previous section. In particular, it is likely to do the following:

- Increase the safety of transport operations in a cost effective way across the entire region.
- Integrate seamlessly with neighbouring regions.
- Improve economic development by creating an on-going high technology venture and stimulating demand for new navigation services.
- To improve regional co-operation, which will be a pre-requisite in establishing a body to manage the ISA and collect charges.

Providing a benefit to transport, particularly aviation, will also deliver socio and macro economic benefits to African economies. An efficient and competitive air transport industry is a pre-requisite to greater international trade. It encourages development and competition of local and national industries. It will deliver, amongst others, the following benefits:

- Increased tourism and greater international links, which will bring economic benefits and foster greater cultural interchange.
- Increased competitive efficiency of the aviation industry. This provides knock-on benefits to other industries that rely on aviation, such as lower transportation costs for their goods.

- Better communications to support local and national industries, to allow them to trade in other parts of the world. This is increasingly important as globalisation continues to dominate world trade.
- Local communities around airports will benefit from increased employment and trade.
- Certain industries, such as logistics, benefit explicitly from efficient airport hubs and the ability to transport good quickly and safety across countries.

8. Recommended Future Actions

The following have been identified to help support a complete cost-benefit analysis for an ISA:

- Increased resources set aside for obtaining both up-to-date and accurate information. This should include annual revenues from air navigation charges, exact numbers of ground navaids in operation and in particular numbers relating to the breakdown of African and non-African international aircraft operating in the AFI region.
- Assessment of possible retrofitting options for aged aircraft. A low-cost SBAS solution for some of these aircraft would reduce the cost to the user community.
- Study into the optimal navigation strategy for the AFI region in terms of the need for DME's as a back-up navigation system if SBAS is available. What would be the minimum density of DME's required for such a back-up and their associated costs (both for operation and possible additional implementations required).
- Actively promote the use of ISA in other user communities. When both the maritime and rail domains gain a similar momentum in respect of the possible benefits from ISA Safety of Life applications, the investigation into a multi-modal cost-sharing scheme could begin. This would further increase the net benefit to the aviation community, enabling the sharing of the infrastructure capital and operating costs required to implement the system.
- Quantification of some of the wider economic benefits of SBAS provision for nations both inside and outside the AFI region.

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[16] Official statistics from the Energy Information Administration
http://www.eia.doe.gov/emeu/cabs/archives/africa/africa.html#economics%20and%20demographics

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