International Civil Aviation Organization
Eastern and Southern African Office

Joint Meeting of the APIRG Performance Based Navigation and Global Navigation Satellite System Implementation Task Forces (Joint PBN & GNSS/I TFs)

First Meeting
(Nairobi, 8 - 10 September 2009)

Agenda Item 8: AFI GNSS Strategy

UPDATE OF ISA AVIATION CBA FOR THE AFI REGION

(Submitted by the European Commission)

SUMMARY

In compliance with Decision 4/1 took at GNSS/I/TF/3, the CBA for ISA has been updated. The scope of this document (coupled with the attached IP) is to present the first version of the updated CBA model, whose effort has been focused on updating numbers of previous CBA, correcting the methodology of previous CBA, validating the model and gather user feedback.

The main benefit for aviation due to ISA roll-out in the AFI region will be the foreseen CFIT reduction (therefore increasing safety of flight in the region), while ground infrastructure represents the highest investment required. ISA cumulated benefits for aviation in the AFI region over a 30-years period will amount to c. €1.7b versus expected investments of c. €359m. Discounted net benefits amount to c. €211m.

TF members are asked to review the CBA in detail and to send comments back to the team by November 2009, before the study is finalised for presentation to APIRG/17.

1. INTRODUCTION

1.1. The first studies on an SBAS for Africa were carried out by the ICAO, ASECNA, ATNS and IATA under an EC Framework back in 1997 and 1999. In 2000, Eurocontrol issued a report which identified the operational value of APVI over existing NPA procedures.

1.2. At the 2nd meeting of the APIRG GNSS Task Force (Johannesburg, June 2004), it was requested that these analyses be updated. In June 2005 a new release of the benefits analysis was issued. These results were presented to the 3rd GNSS TF meeting in June 2005 and at the ISA Potential Investors' Workshop that was held in Cairo in February 2006. Two key AFI ANSPs confirmed their intent to implement ISA REMs in their respective regions of West/ Central Africa and Southern Africa.

1.3. Despite the positive outcome of this workshop, the implementation of ISA was put on hold during 2006 and 2007. In a meeting of the ICAO CNS sub-group in May 2007, a recommendation was made to delay ISA implementation until: "…further cost benefit analysis in coordination with users demonstrates a conclusive need." Their criticisms focused on two main areas:

1.3.1. the benefits analysis did not include the costs of aircraft equipage and procedure development; and only rough costs of the ground infrastructure were supplied;

1.3.2. the level of uncertainty of the overall CBA was high due to the cost impact of counteracting the ionospheric problem over the equator (i.e. should additional RIMS be required for this), the complexity of the regional approach and the lack of user consensus.

1.4. In a further study, Helios Technologies updated their 2005 benefits study and this time included the aircraft equipage costs. These results were presented in the Interregional SBAS for Africa: Contribution to Strategy report of July 2008 and in a more concise Information Paper (IP/7) to the 4th GNSS TF meeting in December 2008.

1.5. There has been a recent revival of interest in ISA as a result of the new ICAO PBN requirements issued by the 36th General Assembly (2007), which states that "States and planning and implementation regional groups (PIRGs) complete a PBN implementation plan by 2009 to achieve:

1.5.1. implementation of RNAV and RNP operations (where required) for en-route and terminal areas according to established timelines and intermediate milestones;

1.5.2. implementation of APV (Baro-VNAV and/or augmented GNSS) for all instrument runway ends, either as the primary approach or as a back-up for precision approaches by 2016 with intermediate milestones as follows: 30 per cent by 2010, 70 percent by 2014."

1.6. Thus, APRIG are faced with agreeing a PBN implementation plan by the end of this year and to this end they will need to decide the technological solution to achieve complete APV capability in AFI by 2016. The 4th GNSS TF highlighted the fact that a decision on a technical solution will have to be taken by the next APIRG meeting (APIRG/17- due to take place in September 2010) in order to meet the PBN deadline for APV.

1.7. The GNSS TF/4 members agreed that SBAS offered superior safety and performance as compared to Baro-VNAV for APV, but also that the cost of implementation was also considerably higher. Thus, the TF agreed that when the case for ISA (SBAS) is presented to APIRG it would have to be strongly justified by a credible CBA. The TF requested that ESA produce a further update of the July 2008 CBA, based on the most up-to-date statistical data on the AFI fleet and flight numbers.

1.8. In compliance with Decision 4/1 took at GNSS/I/TF/3, the CBA for ISA has been updated. The scope of this document (coupled with the attached IP) is to present the updated CBA model, whose effort has been focused on updating numbers of previous CBA, correcting the methodology of previous CBA, validating the model and gather user feedback.

1.9. Update of numbers of previous CBA: The analysis is built upon the last two assessments from 2005 and 2008. Besides taking onboard past and present criticisms of the analyses by African stakeholders, the CBA analyses have been updated in a few key respects as described below:

1.9.1. Timeline: the previous CBA timeline, standing at thirty years starting in 2008, has been adjusted to a more realistic timescale with a start of ISA infrastructure realization in 2011 and full operations by 2016. These dates assume that APIRG will give the go-ahead for ISA at the earliest in 2010 and that a couple of years will be needed to put the required institutional systems in place and before installation of the first RIMS will start. Completion of the system by 2016 will coincide will the PBN requirement for 100% of APV approaches using SBAS. This timeline is also more realistic in that it will give the airlines at least five years to ensure that their fleets have SBAS avionics on board.

1.9.2. African fleet and flight statistics: The previous analysis was based on African flight statistics from 2003/4 and a fleet breakdown which assumed a similar aircraft types to those in Europe. Updated data have been gathered to improve the underlying fleet and flight assumptions used in the CBA.

1.9.3. Besides timeline and fleet statistics, all other relevant CBA inputs (e.g. discount rate, probability of occurrence of DDCs and CFITs, DDC- and CFIT-related costs, statistical value of life in Africa, navaids statistics, etc…) have been updated and/ or validated.

1.10. Correction of the methodology of previous CBA: Improvement of the approach used to estimate costs and benefits and identification of additional benefits and costs related to ISA, correcting the past CBA analysis in a few key respects as described below have been performed:

1.10.1. Benefits for GA (General Aviation): The 2008 study did not include the benefits that will accrue to GA. However, a 2006 study has shown that SBAS has immediate benefits for GA in Europe. GA in Africa is a small but significant sector, and including the GA benefits to this analysis likely to improve the overall net benefits. GA are more likely to use the smaller, regional airports that are not well equipped in ground-based navaids and thus where SBAS will offer marked improvements in safety on approaches.

1.11. Validation of the model and gathering of user feedback: The Costs-Benefits Analysis, updated and reviewed, is a useful but not sufficient tool to support the ISA development. In order to achieve all the objectives, the developed CBA model needs to be validated, primarily by gathering stakeholders' feedback:

1.11.1. An important activity has been the involvement of a major African airline (South African Airways). This was essential in light of one of the criticisms of the CNS SG 2 meeting regarding the lack of user consensus for the ISA CBA. The SAA strongly supports the implementation of SBAS for RNP 0.1 for improved safety and economic savings. In their view Baro-VNAV will not enable APV – only improved NPAs.

1.11.2. EGNOS RNP CBA: A qualitative assessment of the EGNOS RNP option ("Intermediate SBAS") has been included. In the last few months, it has come to light that due to EGNOS operations over the ECAC region, most of Africa is covered by availability of an EGNOS-enhanced RNP (Required navigation performance) capability. This capability will increase the availability of the GPS signal - used in RNP systems together with Baro-VNAV for RNP 0.3 and RNP 0.1 approach procedures – from the currently level of around 90% to 100%. This will allow RNP APCH procedures to be followed even if a critical GPS satellite is not functioning correctly. Note that this capability will facilitate enhanced NPA but not APV.

Upon modification of Message (MSG) 27 - already planned by EGNOS- SBAS capable aircraft can exploit this performance. Thus, this enhanced en-route and NPA (non-precision approach) navigation service is already available over the African continent to 20 degrees south. ESA has estimated that this coverage could be extended over Southern Africa by the addition of 4-5 reference (Regional Integrity Monitoring Stations – RIMS) stations in the region. The technical feasibility of this and the likely location of the RIMS is currently under investigation by ESA. The members of the GNSS TF expressed considerable interest in this capability, and have requested additional information from ESA. This represents a possible "intermediate option" for SBAS implementation in AFI – and at a cost that will be considerably less than for the full ISA system of 27-32 RIMS over sub-Saharan Africa. Due to the newness of the "Intermediate SBAS" concept, very little information is currently available on costs and benefits of such a system. However, this SBAS option would be a distinct possibility for AFI in light of their concerns about the overall cost of the full ISA system (estimated around €50m). The team therefore proposes to carry out an initial CBA of this "intermediate option", looking at the benefits of the enhanced navigation service on offer versus the costs of implementation of the additional RIMS.

2. OUTCOMES OF THE UPDATED ISA CBA FOR AVIATION IN THE AFI REGION

2.1. The main benefit for aviation due to ISA roll-out in the AFI region will be the foreseen CFIT reduction, while ground infrastructure represents the highest investment required:

2.1.1. Allowing Continuous Descent Approaches in place of the higher-risk traditional step-down approach; ISA have a positive impact on CFIT reduction.

2.1.2. Automatic Dependent Surveillance-Broadcast (ADS-B) allows an aircraft to constantly broadcast its precise location and other flight data to nearby aircrafts and air traffic controllers; ISA is expected to improve the performance of the ADS-B system.

2.1.3. ISA is expected to promise less reliance on ground based navaids, determining relevant savings.

2.1.4. Supporting APV, ISA allows lower decision heights in the approaching phase, reducing the probability of occurrence of Delays, Diversions and Cancellations.

2.1.5. ISA will require to install and operate REMs and RIMSs, equip aircrafts with SBAS receivers and update airports' procedures.

2.2. The methodology utilized in the CBA is shared within the industry:

2.2.1. The CBA (which assess the delta from the base line scenario which is Baro-VNAV without SBAS) considers a timeframe of 30 years (from 2011 to 2041) and represents countries that total 84% of nominal African GDP. A 100% penetration of LPV procedures (with 46% being SBAS) on IFR landings is reached by 2020.

2.2.2. For what concerns benefits:

2.2.2.1. IFR landings have been considered the main driver for CFIT, ADS-B and DDC benefits (only for ADS-B en-route radar coverage percentage is a key variable).

2.2.2.2. The benefit for traditional navigational aids phasing out is applied only to VOR and NDB. Ten years to complete the process have been considered.

2.2.3. With regards to opex and investments:

2.2.3.1. Ground infrastructures cost is influenced by the number of REMs and RIMSs and the related capex and opex.

2.2.3.2. The cost for aircraft equipage is mainly driven by the actual fleet. Forward-fit costs are preferred and retrofitting is only applied to the marginal aircraft needed to reach the foreseen EGNOS penetration.

2.2.3.3. The cost for airport procedures is calculated applying the cost of publishing one procedure to the IFR runways discounted by EGNOS penetration.

2.3. ISA cumulated benefits for aviation in the AFI region over a 30-years period will amount to c. €1.7b versus expected investments of c. €359m. Discounted net benefits amount to c. €211m.

2.3.1. Benefits are expected to start in 2016, CFIT, DDC and ADS-B benefits will increase at a 9.3% Compounded Average Growth Rate (CAGR) going forward, while navaids ones will increase at a 3.3% CAGR.

2.3.2. ISA related investments are expected to be important until 2016, whilst after that date mainly operating expenses are foreseen.

2.3.3. Several scenarios analyses (e.g., increasing the discount rate, excluding IATA flights, considering different dates for full penetration of LPV procedures) have been considered. However, under each of those scenarios, cumulative discounted benefits of adopting SBAS for the AFI region remain still largely positive.

3. ACTIONS FOR THE TASK FORCE

3.1. The current meeting represents a key opportunity to present the updated analysis to the GNSS TF. The meeting is the opportunity for all ANSPs to validate the CBA and give their feedback. ANSPs benefit from a deep knowledge of African aviation industry and as ISA main stakeholders, are in the position of proving the most valuable suggestions in relation to ISA related costs, benefits, methodology to be adopted for their validation and most updated inputs.

3.2. TF members are asked to review the CBA in detail and to send comments back to the team (as agreed at the 4th GNSS TF – see GNSS/TF/4/Report) by end of November 2009.

3.2.1. This is an opportunity to request improvements to the study before it is finalised for presentation to APIRG/17.

Joint PBN and GNSS TF Meeting
ISA CBA – Proposed Agenda item 7

Nairobi, Kenya, 8-10 September 2009

DRAFT DOCUMENT

DRAFT DOCUMENT

Agenda

- Introduction
- ISA CBA

CONFIDENTIAL

Scope of this document

- In compliance with Decision 4/1 took at GNSS/I/TF/3, the CBA for ISA has been updated. The scope of this document is to present the first version of the updated CBA model, whose effort has been focused on updating numbers of previous CBA, correcting the methodology of previous CBA, validating the model and gather user feedback.
- The main benefit for aviation due to ISA roll-out in the AFI region will be the foreseen CFIT reduction (therefore increasing safety of flight in the region), while ground infrastructure represents the highest investment required. ISA cumulated benefits for aviation in the AFI region over a 30-years period will amount to c. €1.7b versus expected investments of c. €359m. Discounted net benefits amount to c. €211m.
- TF members are asked to review the CBA in detail and to send comments back to the team by November 2009, before the study is finalised for presentation to APIRG/17.

Note: *

A total of 44 interviews with main ISA stakeholders have been conducted

ISA Stakeholders interviewed (44)

- ACI World, Manager
- ADS-B Technologies, LLC, Director
- Air Traffic and Navigation Services (ATNS), Director
- Airservices Australia, Director for ADS-B program
- Alitalia, Flight Safety Manager
- Ascend, Director
- ASECNA, Chef de Bureau AIS/MAP
- ASECNA, Conseiller technique du Directeur de l'Exploitation
- ASECNA, Manager of the Air Circulation Bureau
- Brown University, Professor
- Brussels Airlines, Flight Safety Manager
- ENAV, Director
- ENAV, Flight Operation Manager
- ESA, Institutional Relations Director
- Eurocontrol, Technical Manager
- Eurocontrol, NAV infrastructure and GNSS activities Manager
- FAA, Director
- FAA, PBN Specialist
- FAA, Satellite Navigation Program Office
- Flight Safety Foundation, Director of Technical Programs
- Garmin, Product Manager
- Honeywell Aerospace, Director, Aerospace Regional Affairs
- Honeywell Aerospace, Senior Strategic Marketing Manager
- ICAO, Implementation & Resource Development Coordinator
- ICAO, Regional Manager
- ICAO, Regional Officer/CNS (WACAF)
- ICAO, RO/CNS
- Kenya Airways, Flight Safety Manager
- MITRE, Director
- National Transportation Safety Board, Safety studies and Statistical Analysis Director
- National Transportation Safety Board, Statistic Director
- NAVCanada, Director, Operational Analysis
- Pildo Labs, Manager
- Politecnico di Torino, Professor
- Princeton University, Professor
- Rockwell Collins, Sales Manager
- Selex, Product Manager
- Sensis, Product Manager
- Sensis, Vice President
- Sia Solutions, Product Manager
- South African Search and Rescue Organization, Director
- Stern University, Professor
- Thales, Technical Manager
- The World Bank, Manager

Moreover, a comprehensive list of 19 secondary sources has been reviewed

Secondary sources reviewed (19)

- Africa-Indian Ocean Regional Traffic Forecasts 2004–2020; ICAO – Working paper; Feb-06
- Air Nostrum: Business case for SBAS equipage; GIANT; Dec-06
- Approach to Assess the Benefits and Costs of ATM Investments; EUROCONTROL; Mar-03
- Automatic Dependent Surveillance – Broadcast (ADS-B) seminar and the sixth meeting of ADS-B study and implementation Task Force (ADS-B SITF/6); ICAO – Working paper; Apr-07
- Country Default Spreads and Risk Premiums; Damodaran; 2007
- EMOSIA - Air Navigation Service Provider Model; EUROCONTROL/ Boeing; Mar-05
- EMOSIA - Airport Model; EUROCONTROL/ Boeing; Mar-04
- EMOSIA - Model Architecture and Approach; EUROCONTROL/ Boeing; Jul-03
- Evaluating the true cost to airlines of one minute of airborne or ground delay; EUROCONTROL; May-04
- Inter-regional SBAS for Africa - Review of benefits; Helios; May-05
- Interregional SBAS for Africa: Contribution to Strategy; Helios; Jul-08
- ISA Aviation Business Case Information Paper; Helios; Dec-08
- ISA Funding Options Analysis; ESYS; Jun-06
- ISA service implementation plan; Progeny; Nov-07
- Operational service framework for Inter-regional SBAS for AFI (ISA); Progeny; Nov-07
- Project ATLAS – Cost Benefit Analysis; Access Economics; Jun-07
- Project Profile: ISA Regional Module for West and Central Africa; ASECNA; 2007
- Standard Inputs for EUROCONTROL Cost Benefit Analyses; Eurocontrol; Feb-05
- Third Meeting of the AFI GNSS Implementation Task Force; ICAO; Jun-05

The methodology utilized in the CBA is shared within the industry

- In general:
  - The CBA considers a timeframe of 30 years (from 2011 to 2041) and represents countries that total 84% of nominal African GDP
  - A 100% penetration of LPV procedures (with 46% being SBAS) on IFR landings is reached by 2020
  - The CBA considers the delta from the base line scenario which is Baro-VNAV without SBAS
- For what concerns benefits:
  - Landings is the main driver for CFIT, ADS-B and DDC benefits
    - only IFR landings are considered and within these only the specific share related to EGNOS influences the calculations
    - also LPV penetration influence the number of landings considered
    - in addition only for ADS-B en-route radar coverage percentage is a key variable
  - The benefit for traditional navigational aids phasing out is applied only to VOR and NDB. Ten years to complete the process have been considered
- With regards to opex and investments:
  - Ground infrastructures cost is influenced by the number of REMs and RIMSs and the related capex and opex
  - The cost for aircraft equipage is mainly driven by the actual fleet
    - only IFR aircraft are considered and within these only the specific share related to EGNOS influences the calculations
    - forward-fit costs are preferred and retrofitting is only applied to the marginal aircraft needed to reach the foreseen EGNOS penetration
  - The cost for airport procedures is calculated applying the cost of publishing one procedure to the IFR runways discounted by EGNOS penetration

Agenda

- Introduction
- ISA CBA

Main benefits will be CFIT reduction and ADS-B implementation, while ground infrastructure represents the highest investment required

	Benefit/ Cost	Description	ISA Relevance
Benefits	CFIT probability reduction	ISA will increase flight safety through the reduction in the number of Controlled Flight Into Terrain (CFIT) occurrences by offering Approaches with Vertical Guidance	●
	ADS-B improvement	Supporting Automatic Dependent Surveillance Broadcast (ADS-B), ISA will allow flight routes optimization, with consequent fuel savings over ADS-B using GPS only	◕
	Traditional navigational aids replacement	ISA will determine significant cost savings related to both installation and maintenance of traditional ground based navigational aids (navaids)	◕
	DDC probability reduction	Enabling Approaches with Vertical Guidance with consequent lower decision heights, ISA will significantly reduce the probability of occurrence of Delays, Diversions and Cancellations	◔
Investments/ Costs	Ground infrastructure	ISA will rely upon a series of infrastructure to be deployed and maintained across the African territory (Regional Extension Modules and Reference and Integrity Monitoring Stations)	●
	Aircraft equipage	African fleet needs to be equipped with SBAS receivers, either through a retrofit or forward-fit process	◔
	Airport procedures	In order to support SBAS-based approached, specific airport procedures must be defined	◔

Allowing Continuous Descent Approaches in place of the higher-risk traditional step-down approach, ISA have a positive impact on CFIT reduction

Controlled Flight Into Terrain (CFIT) and Non-Precision Approaches (NPA)

Graphical support

Context description

- CFIT occurs when an airworthy aircraft under the control of the flight crew is flown unintentionally into terrain, obstacles or water, usually with no prior awareness by the crew
- This type of accident can occur during most phases of flight, but CFIT is more common during the approach-and-landing phase
- Non-Precision Approaches are at the basis of CFIT occurrence

ISA benefits

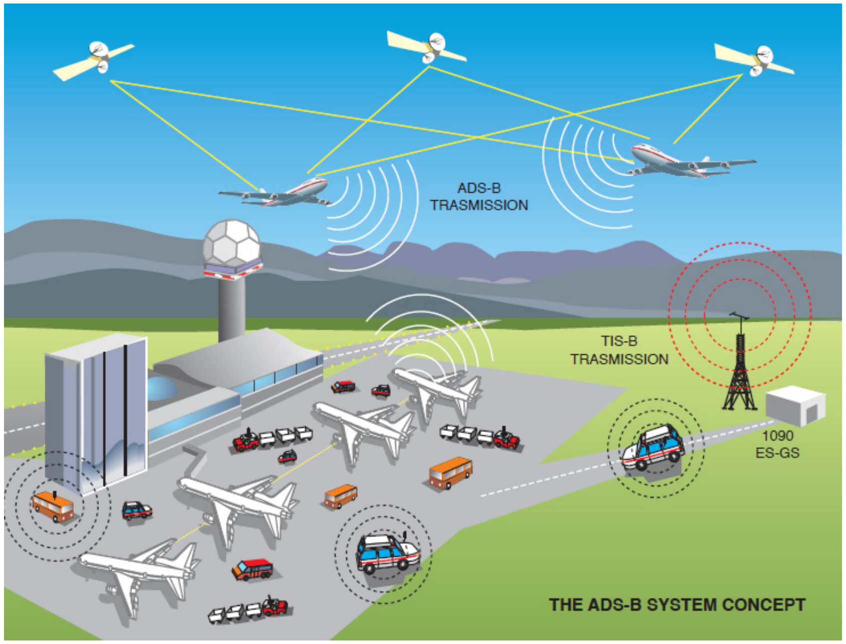
- Offering Approaches with Vertical Guidance procedures and enabling Continuous Descent Approaches, ISA can lead to a decrease in the number of CFIT occurrences

  "… ISA will have an extremely positive impact on flight safety, determining almost a 100% CFIT avoidance …"

Automatic Dependent Surveillance-Broadcast (ADS-B) allows an aircraft to constantly broadcast its precise location and other flight data to nearby aircrafts and air traffic controllers

The ADS-B system concept

Graphical support



Context description

- C.55% of total flights in Africa are not supported by surveillance services provided enroute radars
- In such situation aircrafts are obliged to flight respecting a so called procedural separation of c.50NM, far above the optimized one of c.5NM
- African routes are consequently un-optimized

ISA benefits

- SBAS is expected to improve ADS-B based on GPS only
- Enabling a more accurate aircraft positioning, ISA-based ADS-B allows a better route optimisation with respect to GPS only

“…ISA is expected to improve ADS-B performance providing a further optimisation over GPS only-based ADS-B …”

ISA is expected to promise less reliance on ground based navaids, determining relevant savings

Ground aids (ILS, DME, VOR and NDB) replacement

Graphical support

Context description

- Traditionally navigation in Africa is guided by a series of ground based navaids: ILS, DME, VOR and NDB
- The operation and maintenance of ground-based navigation aids represent a major cost element of air navigation service provision

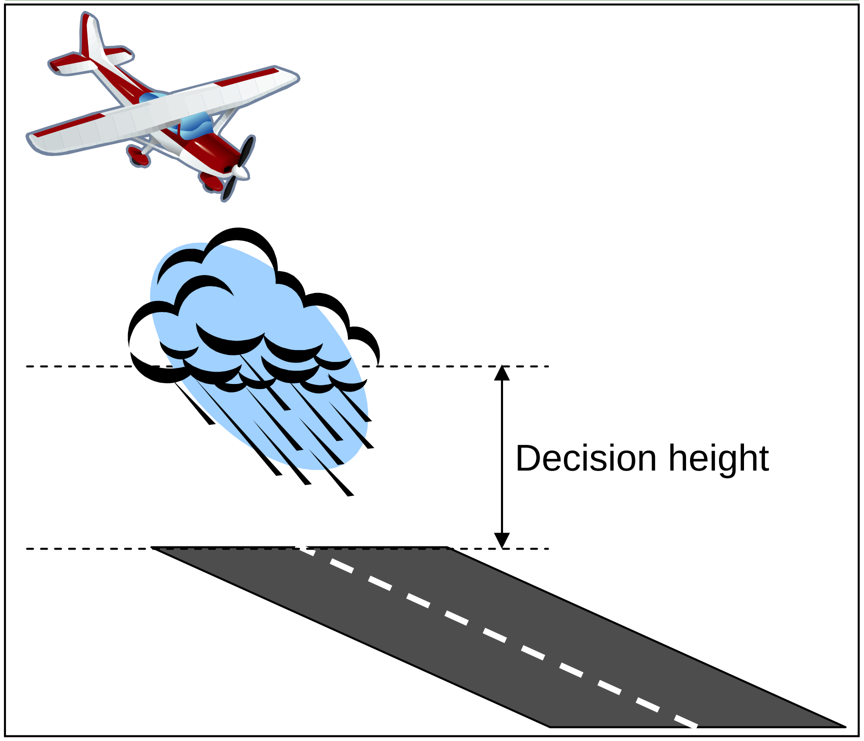
ISA benefits

- The introduction of ISA would allow the phasing out of some of these conventional navaids (only VOR and NDB), bringing significant benefits in terms of both capex and opex savings
  - "…The deployment of ISA will determine the replacement of ground aids, reducing both operational and capital expenditures …"

Supporting Approaches with Vertical Guidance (APV), ISA allows lower decision heights in the approaching phase, reducing the probability of occurrence of Delays, Diversions and Cancellations

The importance of the decision height in the approaching phase

Graphical support



Context description

- The decision height is the minimum altitude at which a missed approach can be initiated if deemed unsafe by the pilot allowing sufficient time to safely re-configure the aircraft to climb and execute the missed approach procedures while avoiding terrain and obstacles
- Reducing the decision height at an airport will help reduce the number of Delays, Diversions and Cancellations experienced by the airlines

ISA benefits

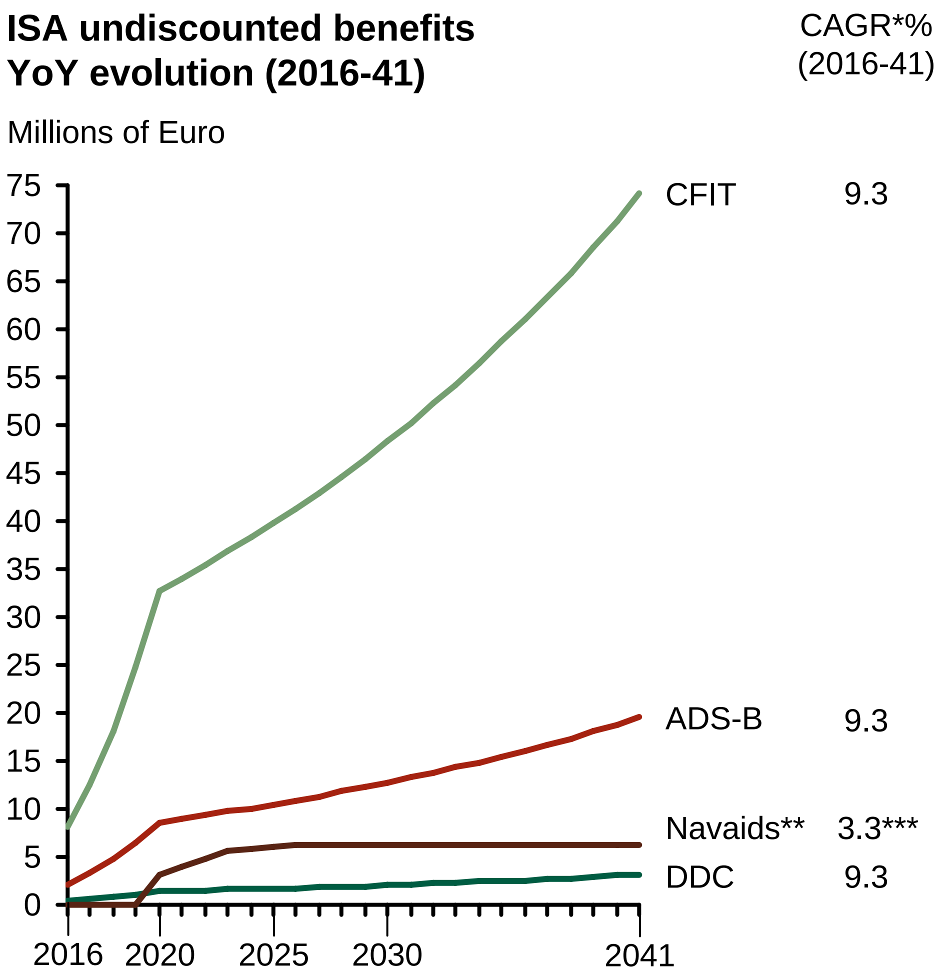
- ISA allows for SBAS-based Approaches with Vertical Guidance (APV), which enable lower minima

> "…Although on average Africa is characterized from better weather conditions than Europe, African aviation will benefit from ISA in terms of DDC occurrence reduction …"

Benefits are expected to start in 2016, CFIT, DDC and ADS-B benefits will increase at a 9.3% CAGR going forward, while navaids ones will increase at a 3.3% CAGR

ISA undiscounted benefits YoY evolution (2016-41)

Millions of Euro



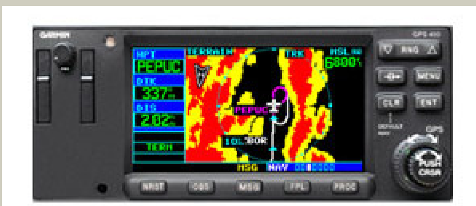
- The avoidance of CFIT constitutes the greatest benefit of ISA

  "… Safety related benefits represent the most relevant advantage of ISA adoption …"

- Traditional navaids replacement benefit shows a growing trend over the first years of ISA adoption, followed by a stable phase; such trend is determined by traditional navaids backlog phasing out and maintenance costs reduction

Note: * Compounded Average Growth Rate; * *VOR and NDB; *** CAGR% 2020-41

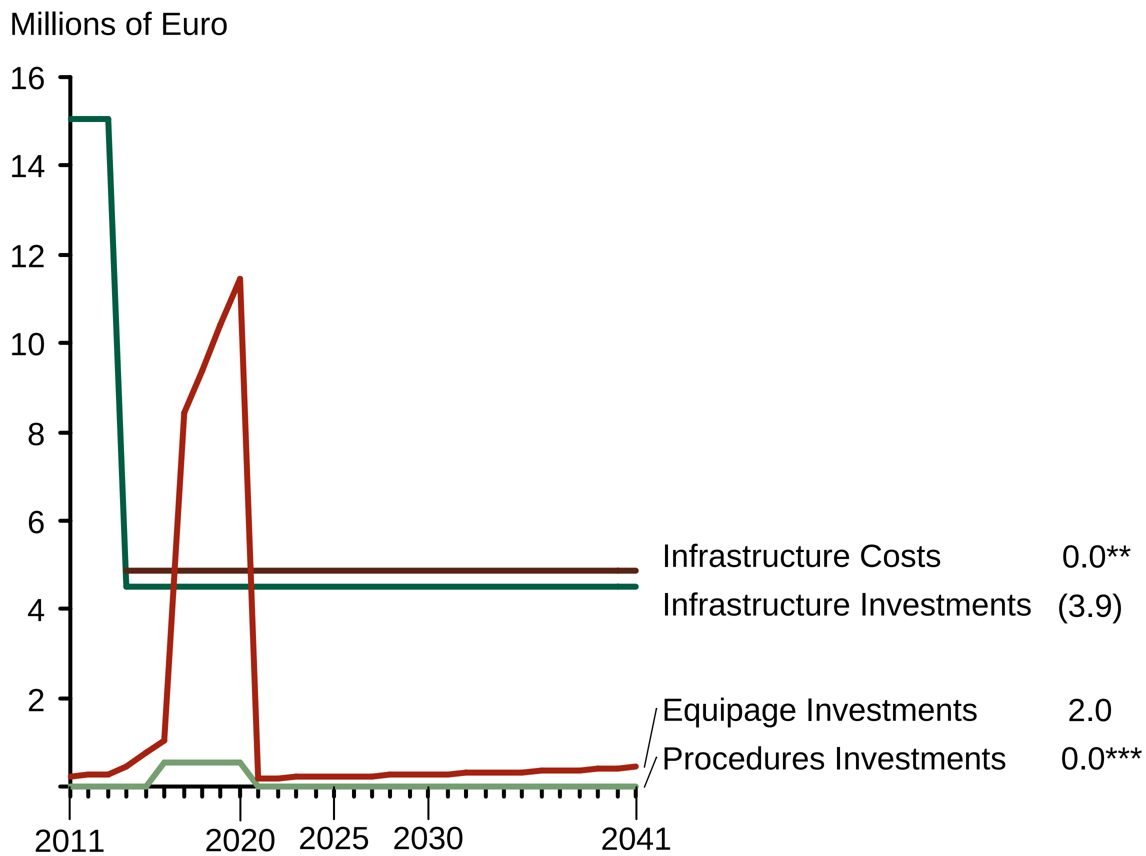
ISA will require to equip aircrafts with SBAS receivers, update airports' procedures and install and operate REMs and RIMSs

	Aircraft equipage	Airport procedures	Ground infrastructure deployment and maintenance
Graphical support			
Context description	• SBAS receivers require an update of GPS or multi-mode receivers thus being enabled to receive the signal • Aircrafts need to be equipped with SBAS receivers "… The exploitation of ISA benefits largely depends upon the adoption by airlines of both SBAS and ADS-B equipment …"	• Approach and landing runway procedures define the rules to be observed in the final phase of a flight "… The introduction of ISA will determine the definition of new procedures for runway ends …"	• Regional Extension Modules (REM) are used for integrating, monitoring and controlling additional RIMSs (Ranging and Integrity Monitoring Station) deployed for ISA "… ISA will rely upon a series of infrastructures (REM and RIMS) to be deployed across African territory …"

CONFIDENTIAL

ISA related investments are expected to be important until 2016, whilst after that date mainly operating expenses are foreseen

ISA undiscounted investments and costs YoY evolution (2011-41)



- Infrastructures deployment is the main investment for ISA implementation
  - investments are mainly associated to 2 REMs and 30 RIMSs realization

  "…The realization of ground structures will account for the largest share of total expenditures associated to ISA deployment …"

- Equipage is the second investment for EGNOS implementation
  - the costs considered are for the full avionic and not only for the incremental part due to EGNOS upgrade, indeed they can be overestimated
  - the hypothesis is to prefer forwardfitting when possible^

- Procedures costs^^ have been assumed to concentrate in 2016, when SoL signal will be certified

  "…Procedures for airports can be published only after SoL signal certification …"

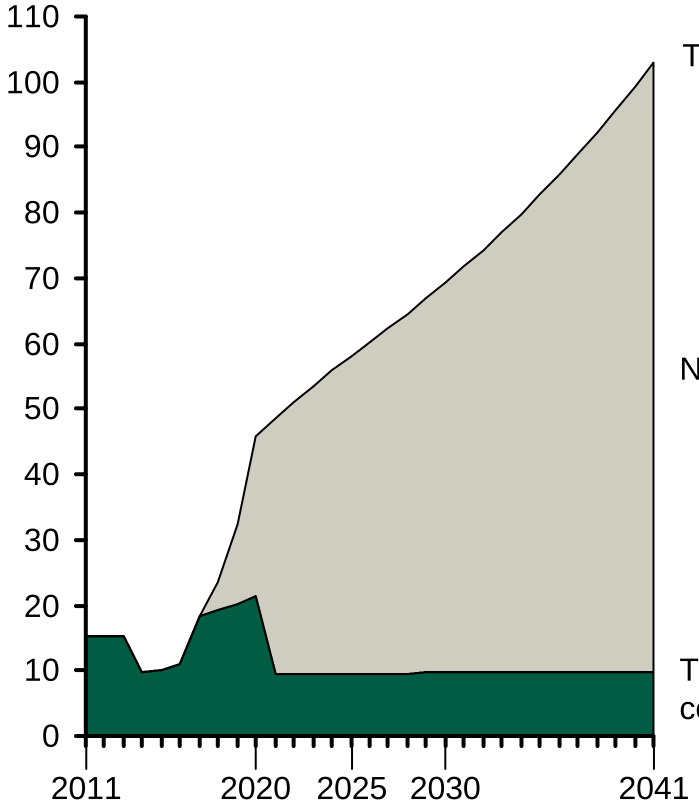
Note: * Compounded Average Growth Rate; ** CAGR% 2014-41; *** CAGR% 2016-20; ^ opportunity costs such as time lost because the aircraft is in maintenance are not considered; ^^ c.115 runways representing 46% of total IFR approaches in Africa

The economic value of ISA benefits will be higher than investments necessary for its deployment and running costs

ISA undiscounted Net benefits YoY evolution (2011-41)

Millions of Euro

CAGR*% (2011-41)



Note: * Compounded Average Growth Rate; ** CAGR% 2016-41; *** CAGR% 2018-41

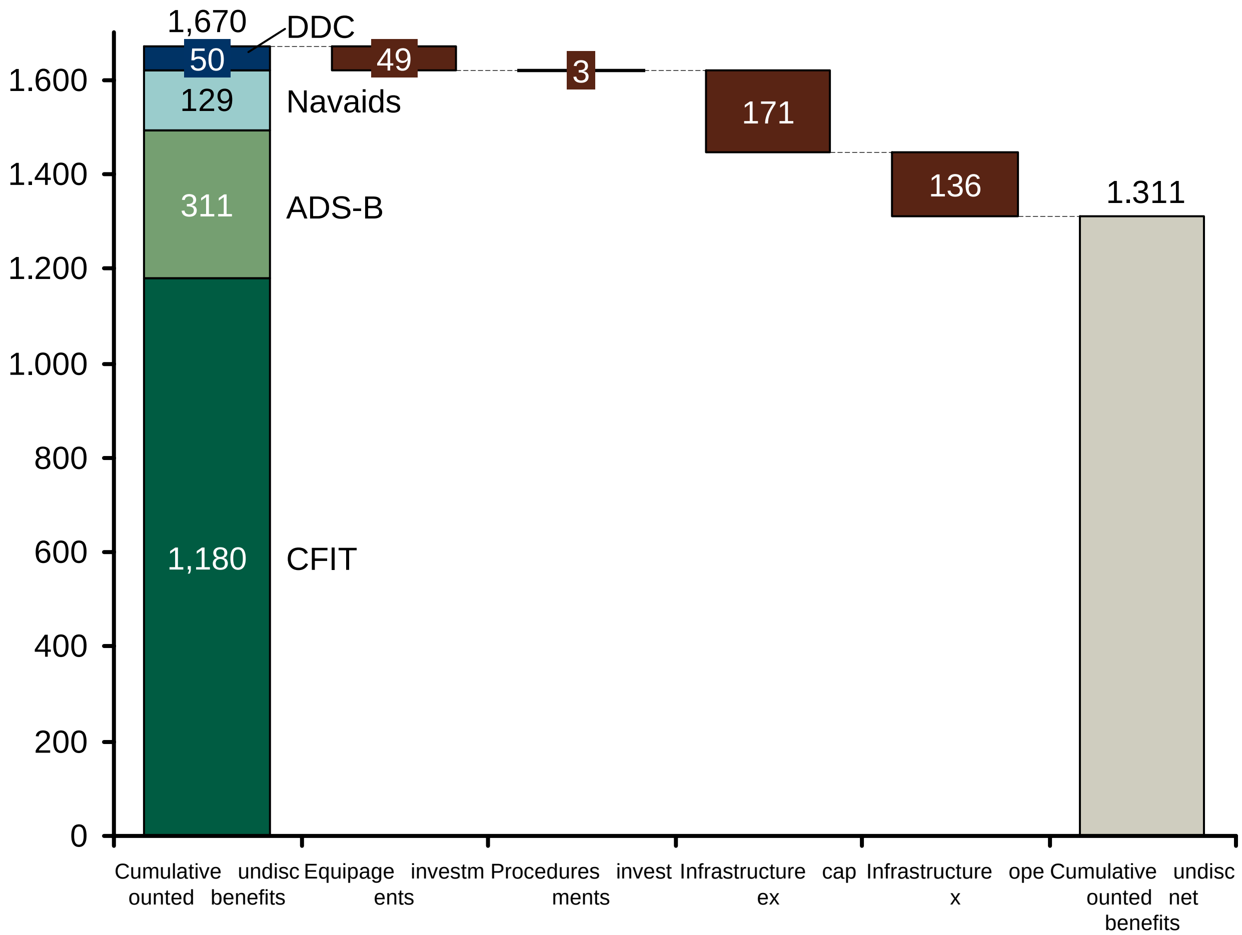
- ISA benefits are expected to exceed investments and costs associated to its implementation and operation
  - total benefits are estimated to amount to c. €102.9m in 2041, with a CAGR* of 9.5% over the 2016-41 period
  - in the same year, total investments and cost are expected to be c.€9.8m, with a 2011-41 CAGR* of (1.5%)

"…I expect that ISA will bring significant benefits for African aviation, guaranteeing higher efficiency and higher safety standards …"

ISA cumulated benefits will amount to c. €1.7b versus investments of c. €359m

ISA cumulative undiscounted net benefits on a 30 years timeframe (2011-41)

Millions of Euro



Discounted net benefits* 211.1€m

Note: * The same discount rate of previous ISA CBA, i.e. 8%, has been used

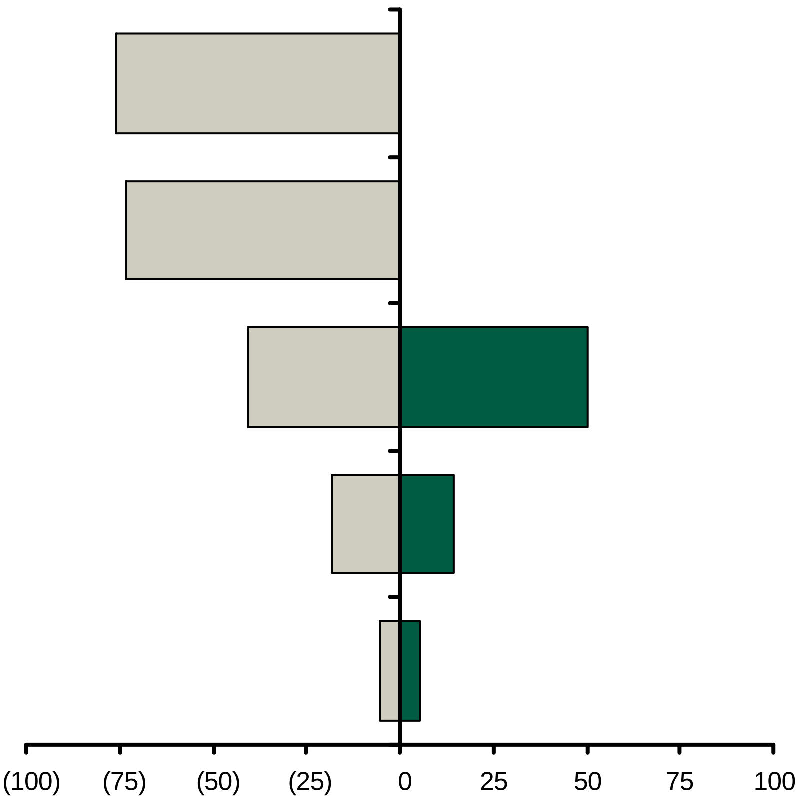
Increasing the discount rate and excluding IATA flights have the highest negative impact on benefits, which remain though still largely positive

Model sensitivity analysis

Millions of Euro

	Worst case	Base case	Best case
Discount rate %	10.0	8.0	-
IATA flights*	OUT	IN	-
CAGR**% landings	3.5	4.1	5.0
% IFR	85.2	90.4	94.5
% of DDC avoidable	22.6	48.5	74.3

Delta vs Base case (211.1 €m)
Net cumulated discounted benefits (2011-41)



Note: * c. 293,873 landings in 2007 out of 1,283,797 landing in all the region; ** Compounded Average Growth Rate

Three scenarios have been identified considering different dates for full penetration of LPV procedures …

ICAO rule

As part of the Strategy for the implementation of GNSS, ICAO has stated the introduction of the use of GNSS with appropriate augmentation systems

> "… States and planning and implementation regional groups (PIRGs) complete a PBN implementation plan by 2009 to achieve: implementation of RNAV (Area Navigation) and RNP (Required Navigation Performance) operations (where required) for en-route and terminal areas according to established timelines and intermediate milestones; and implementation of approach procedures with vertical guidance (APV) (Baro-VNAV and/or augmented GNSS) for all instrument runway ends, either as the primary approach or as a back-up for precision approaches by 2016 with intermediate milestones as follows: 30 per cent by 2010, 70 percent by 2014 …"
>
> Report of the 36th ICAO General Assembly resolution A36-23

	ICAO adoption scenario	2020 adoption scenario (Base case)	2025 adoption scenario
100% penetration of LPV procedures on IFR landings*	2016, with a 30% by 2010 and 70% by 2014	2020, with a constant increase from 2009 to 2020	2025, with a constant increase from 2009 to 2025
ISA market share according to different scenarios	20% (2016 to 2041)	20% to 46% (2016 to 2020) 46% (2020 to 2041)	20% to 46% (2016 to 2020) 46% to 53% (2020 to 2025) 53% (2025 to 2041)

Note: * c. 90% of total landings. Adoption by air fleets and airports' procedures [%]

… and leading to different net benefits results for ISA CBA

	ICAO adoption scenario	2020 adoption scenario	2025 adoption scenario
Full LPV implementation date	2016	2020	2025
Total Benefits			
Discounted	194.2€m	346.5€m	342.1€m
Undiscounted	855.1€m	1,670.1€m	1,774.5€m
Total Costs			
Discounted	115.3€m	135.5€m	135.8€m
Undiscounted	314.5€m	359.0€m	361.1€m
Net Benefits			
Discounted	78.9€m	211.1€m	206.3€m
Undiscounted	540.6€m	1,311.1€m	1,413.4€m

SBAS for LPV

- The objective: enabling LPV operations for the very many aircraft that do not have barometric vertical navigation (Baro-VNAV) capabilities

Baro-VNAV Capable Operations

MITRE Estimates

The US case

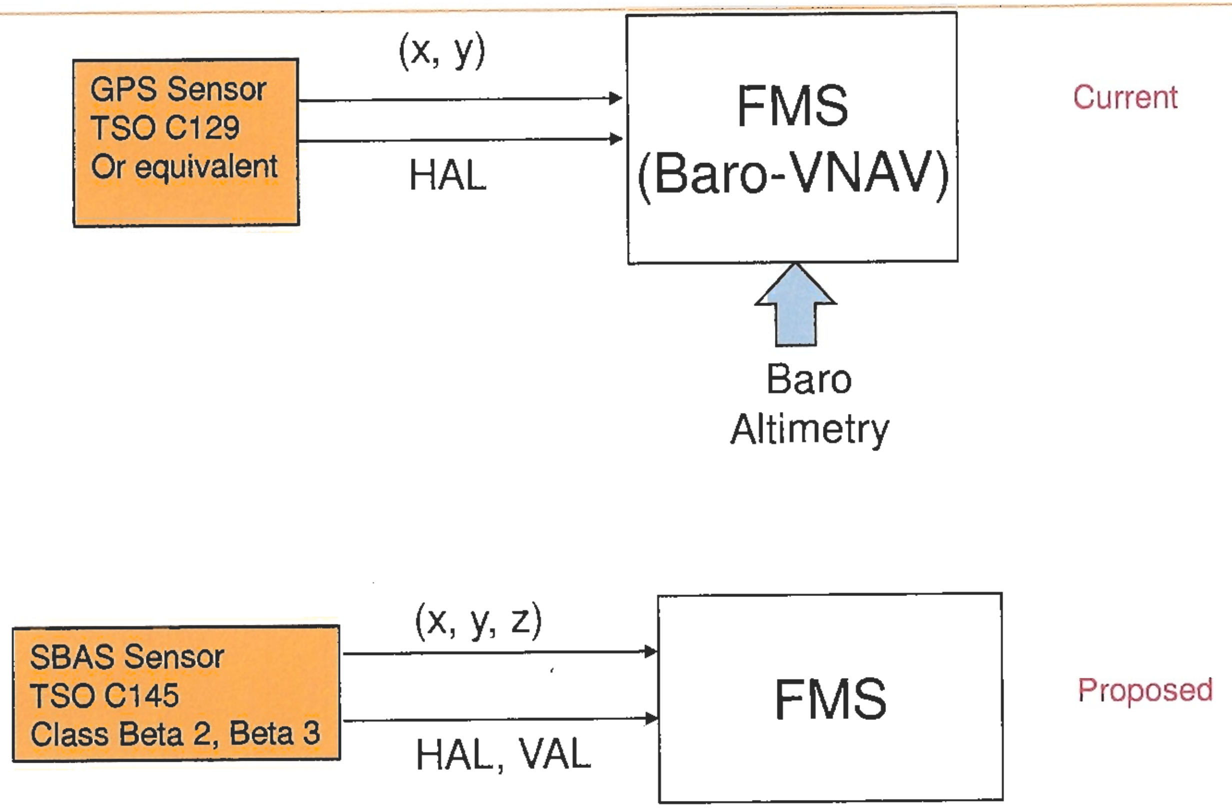
Airline Classification	Number of Aircraft	Number of FMS	Number of VNAV Capable FMS	FMS (%)	Baro-VNAV Capable (%)
10 Major Airlines	3642	3466	3003	95%	82%
Regional Airlines	2325	2151	179	93%	8%
Other Part 121 Airlines	405	316	262	78%	65%
Part 121 Cargo Airlines	1077	610	538	57%	50%
Business Jet Operators	709	640	135	90%	19%
Summary	8158	7183	4117	88%	50%

* CAASD does not have a comprehensive avionics database of Business Jet Operators. These data reflects a very small portion of this classification, and may not accurately depict the capability of this classification.

MITRE

The solution: using vertical guidance from SBAS

Nominal AR Architectures

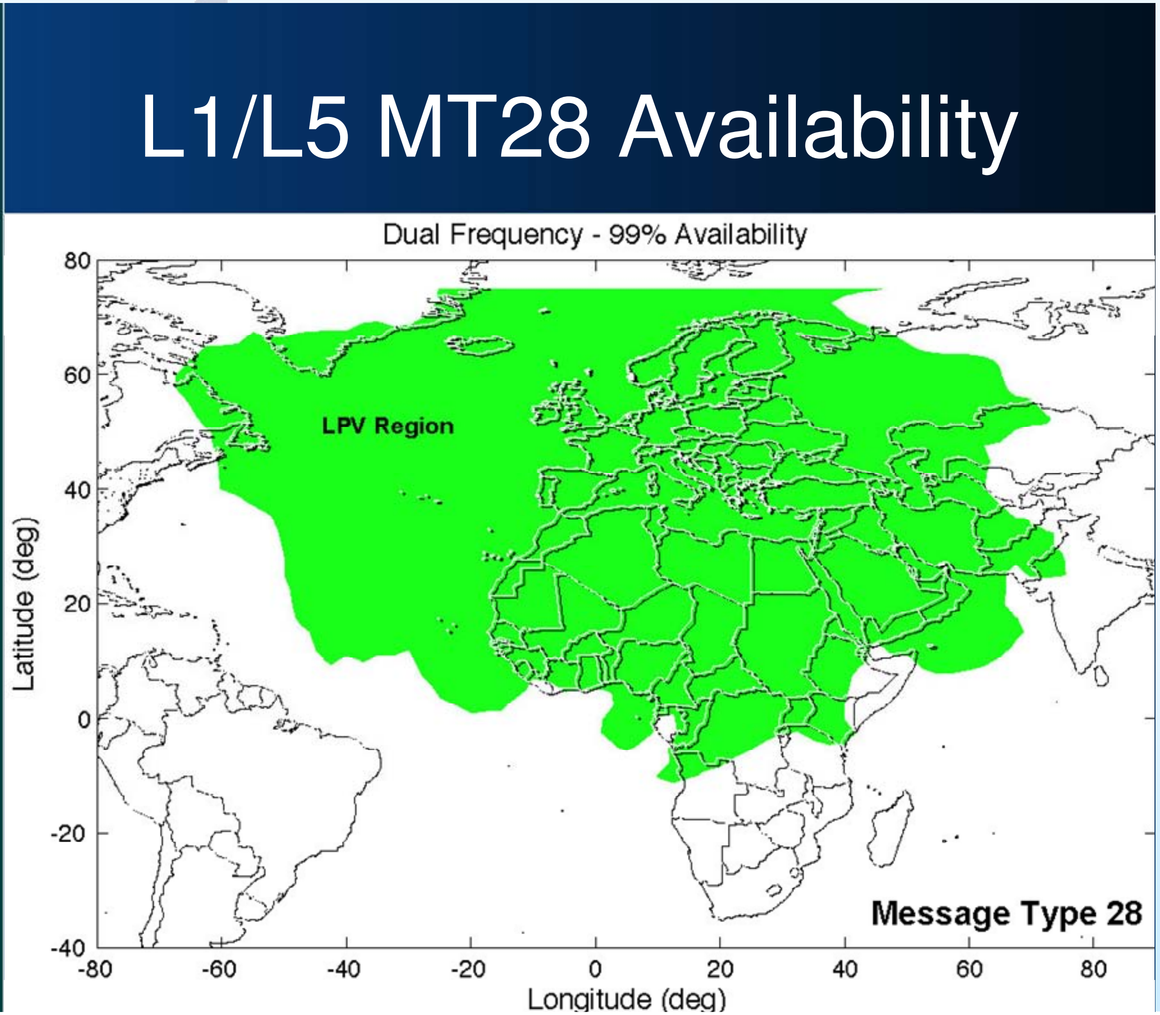


FMS: Flight Management System
HAL: Horizontal Alert Limit
VAL: Vertical Alert Limit

MITRE

Providing SBAS LPV coverage over AFI

- Stanford University studies indicate that widespread LPV coverage over AFI can be obtained by dual frequency L1-L5 users by implementing MT 28



- Few additional EGNOS RIMS in Southern Africa are needed to complete LPV coverage over AFI

SBAS LPV 200
for Phase II of AFI GNSS Strategy

- Upon implementation of MT 28 in EGNOS, dual frequency SBAS capable aircraft can exploit LPV 200 performance over wide areas of AFI

- Completion of LPV 200 coverage over AFI requires installation of additional EGNOS RIMS stations

- SBAS LPV200 functional capability by EGNOS should be duly considered for approach and landing operations during Phase II of the AFI GNSS strategy and in the PBN workplan

Conclusion

- Based on EGNOS, the implementation of SBAS over AFI should be considered for:
  - Provision of RNP 0.1 and 0.3 during Phase I of the AFI GNSS strategy
  - Provision of LPV 200 performance during Phase II of the AFI GNSS strategy
  - Support to ADS-B

- The resulting AFI GNSS strategy shall coherently be reflected in the PBN workplan

AFI GNSS Implementation Roadmap
The role of SBAS

ICAO APIRG
Joint PBN & GNSS/I TFs
Nairobi, 8 - 10 September 2009

esa

The role of SBAS in the US FAA GNSS strategy

RNP and ADS-B in radar airspace (RAD) Enabled with GNSS PNT

	Navigation ($\geq$ 99.0% Availability)		Surveillance* ($\geq$99.9% Availability)				Positioning
	Accuracy (95%)	Containment (10^{-7})	Separation	NACp (95%)	NIC	SIL	GNSS PNT
En Route	10 nm	20 nm	5 nm	0.1 nm (7)	1 nm (5)	(10^{-7}) (3)	GPS
	4 nm	8 nm					
	2 nm	4 nm					
Terminal	1 nm	2 nm	3 nm	0.05 nm (8)	0.6 nm (6)	(10^{-7}) (3)	SBAS
LNAV	0.3 nm	0.6 nm					
RNP	0.1 nm	0.2 nm	2.5 nm DPA	0.05 nm (8)	0.2 nm (7)	(10^{-7}) (3)	
LPV	16m/4m	40m/50m	2.5 nm DPA	0.05 nm (8)	0.2 nm (7)	(10^{-7}) (3)	
LPV-200	16m/4m	40m/35m					
GLS Cat-I	16m/4m	40m/10m	2.0 nm IPA	121 m (8)	0.2 nm (7)	(10^{-7}) (3)	GBAS
GLS Cat-III	16m/2m	40m/10m					

Dependent Parallel Approach (DPA)
Independent Parallel Approach (IPA)

Surveillance Integrity Level (SIL)
Navigation Integrity Category (NIC)

Navigation Accuracy Category for Position (NACp)

*Based on information received from ADS-B Program Office/Flight Standards. Final Chart in coordination.

SBAS on-board capability status

- SBAS-capable on-board avionics is steadily wide-spreading and becoming the de-facto GNSS standard, also in large aircraft (e.g. Airbus A350)

SBAS Avionics Status

- **Garmin:**
  - 43,000+ WAAS LPV receivers sold
  - Currently sole GA panel mount WAAS Avionics supplier
- **AVIDYNE & Bendix-King:**
  - SmartDeck glass panel and KSN-770 projected to market summer 2009
- **Universal Avionics:**
  - Full line of UNS-1 Flight Management Systems (FMS) achieved avionics approval Technical Standards Orders Authorization (TSOA) in 2007/2008
  - 700+ units sold (est. 500+ aircraft configured)
- **Rockwell Collins:**
  - Multiple recent (fall '08) WAAS Sensor/Rcvr & FMS avionics Technical Standards Orders Authorization (TSOA)
- **CMC Electronics:**
  - Achieved Technical Standards Orders Authorization (TSOA) certification on both their 5024 & 3024 WAAS Sensors
- **Honeywell:**
  - Multiple FMSs to achieve WAAS acft cert. in 2009
- **NextNav**:
  - TSO-145c/DO-229D approved WAAS (mini) Beta1 and (Max) Beta 1,2,3 sensors

IWG 18 Meeting
June 17, 2009

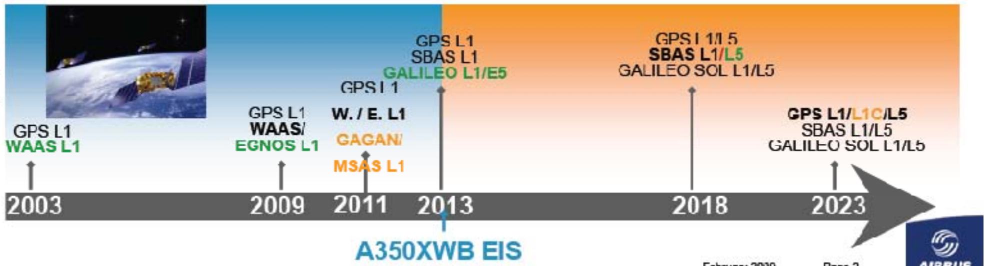
Federal Aviation Administration

Satellite Landing System

Allows to fly RNAV (GNSS) approaches with vertical guidance down to 200ft without any xLS ground station

First step: A350XWB EIS
- Targeted procedures: RNAV GNSS with LPV minima (down to 200')
- Technical enabler: GPS+SBAS
- Coverage: multi regional
- Cockpit integration (HMI, NDB, ..)

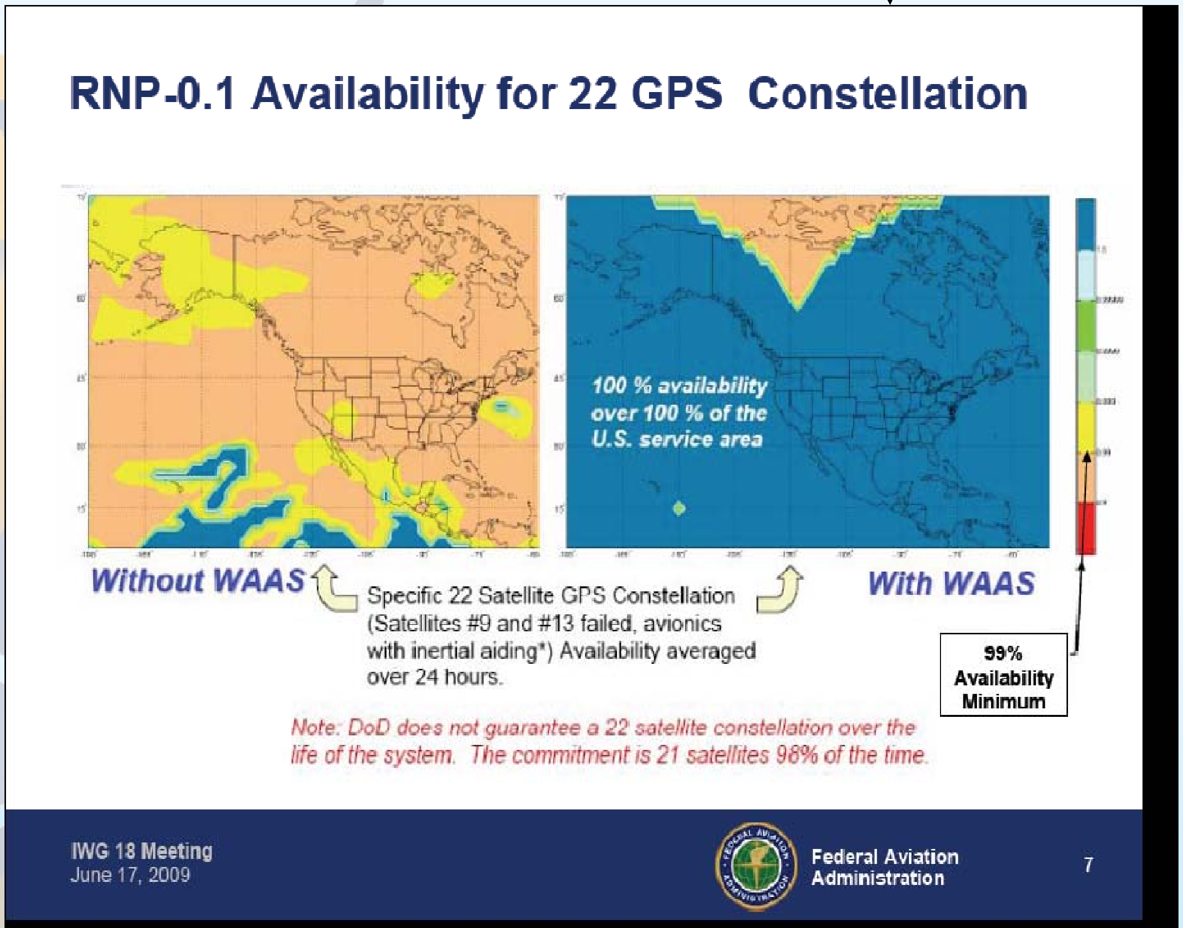
Future steps:
- Technical enablers: all new GNSS means capable of LPV200'
- Coverage: worldwide



February 2009 Page 2

SBAS for RNP 0.1 and 0.3 (1)

- GPS-RAIM or GPS-RAIM-INS not robust to GPS failures



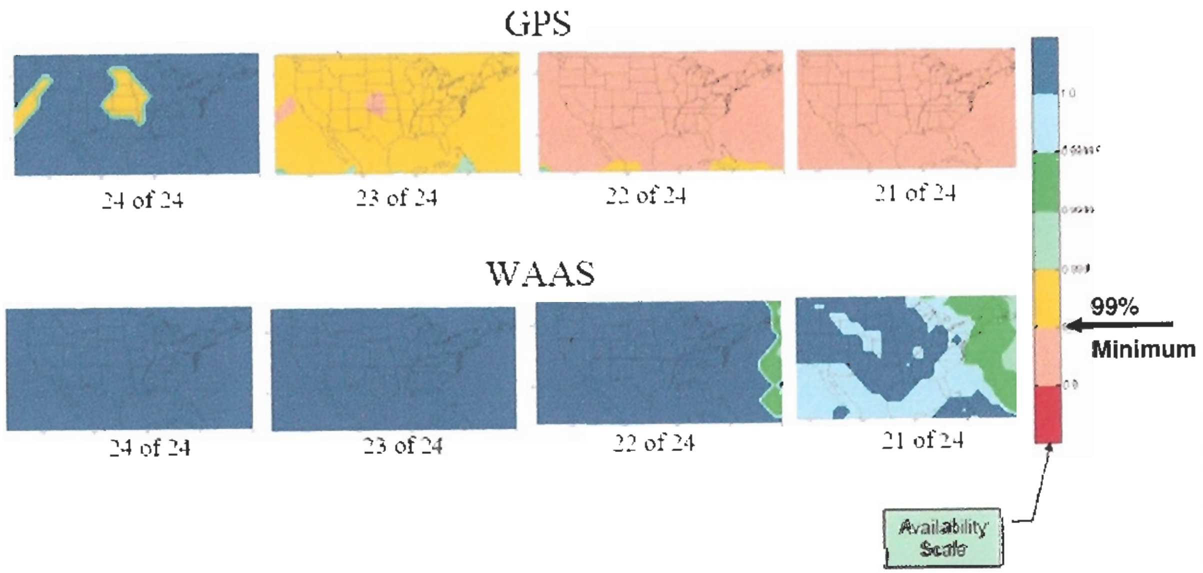
- Outages are shown for the US airspace
- The same occurs over AFI

SBAS for RNP 0.1 and 0.3 (2)

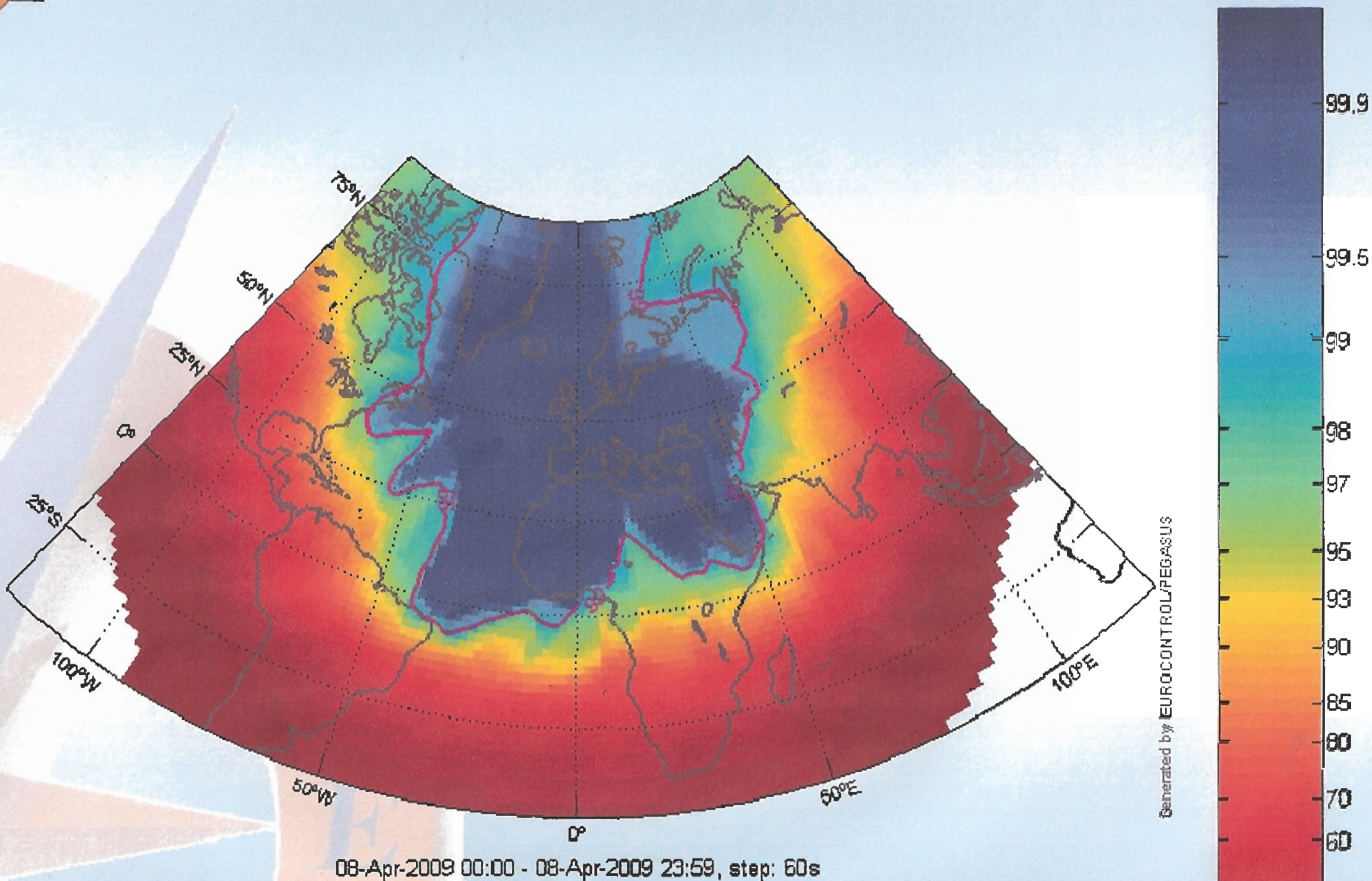
- FAA studies demonstrate that SBAS is needed to ensure robustness to GPS failures, even for NPA

LNAV (RNP-0.3) Availability

(Standard and Degraded GPS Constellations)

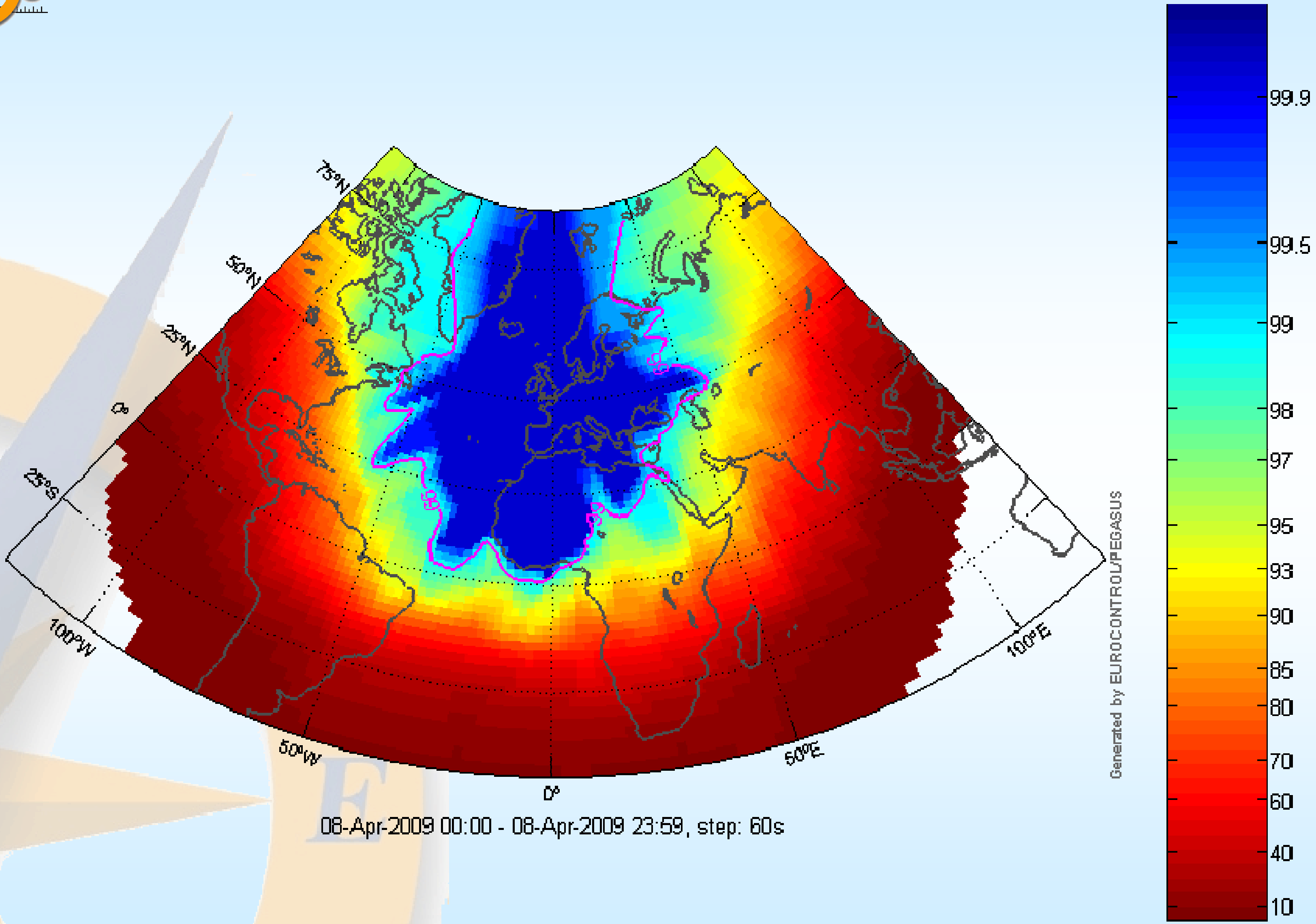


Current SBAS NPA Coverage with 29 GPS*



* Usable upon planned MSG27 modification

Current SBAS NPA Coverage with 24 GPS*

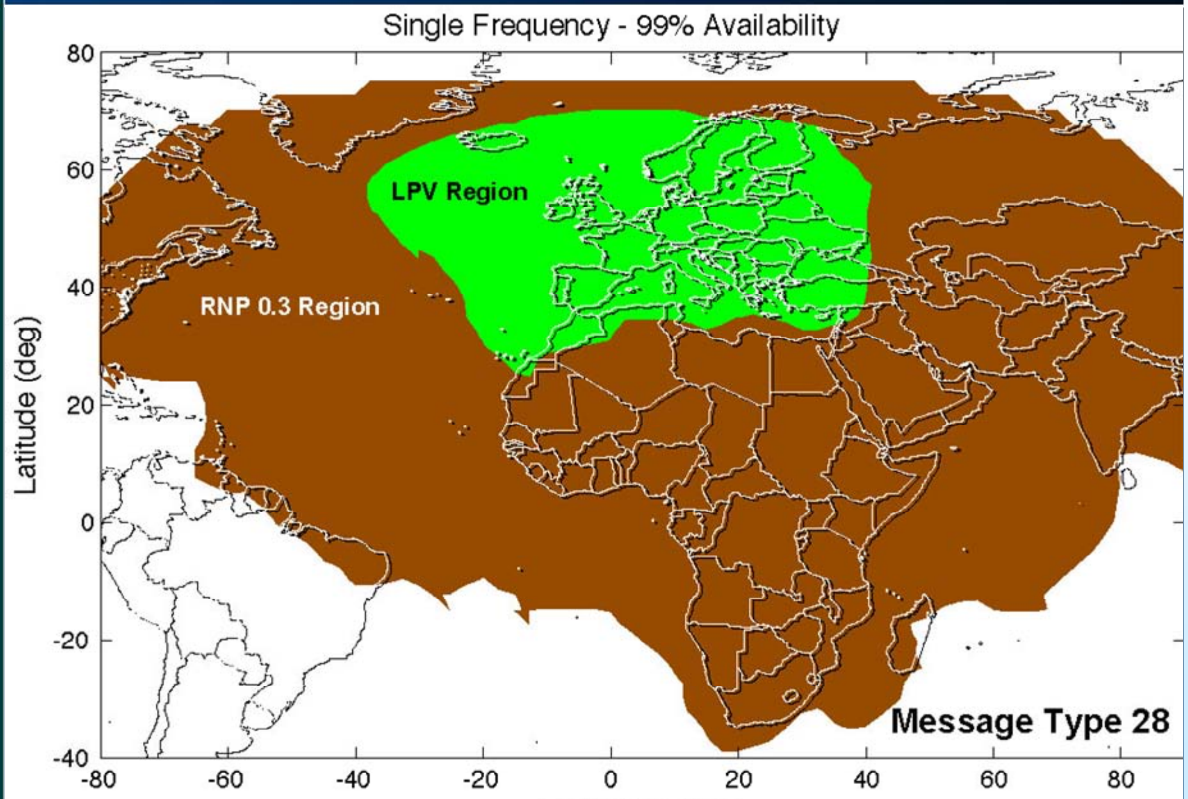


* Usable upon planned MSG27 modification

Completing SBAS RNP 0.3 coverage over AFI

- Initial Stanford University studies indicate that RNP 0.3 coverage over AFI may be completed without additional EGNOS infrastructure

L1 MT28 Availability



- Further studies are launched by ESA to assess whether implementing MT28 is sufficient or some additional EGNOS RIMS in South Africa are needed

SBAS RNP 0.1 and 0.3 for Phase I of AFI GNSS Strategy

- RNP 0.1 and 0.3 performance is already achieved today in wide AFI areas by means of EGNOS, SBAS being the only GNSS technique enabling to fully meet the relevant ICAO availability requirements

- Upon modification of MSG 27 (already planned by EGNOS), SBAS capable aircraft can exploit this performance

- The availability over AFI of SBAS RNP 0.1 and 0.3 performance cannot be ignored for the benefit of SBAS-capable aircraft

- Therefore, SBAS RNP 0.1 and 0.3 functional capability by EGNOS shall be duly (and de-facto) considered already during Phase I of the AFI GNSS strategy and in the PBN workplan