INTERNATIONAL CIVIL AVIATION ORGANIZATION

AFI PLANNING AND IMPLEMENTATION REGIONAL GROUP
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(Burkina Faso, 2 to 6 August 2010)

ISA (Inter-regional SBAS for Africa) CBA update - Final Presentation -

L.E.K.

ISA (Inter-regional SBAS for Africa) CBA update
- Final Presentation -

31st May 2009

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Agenda

- Project objectives
- Executive summary
- Outputs
- Model design methodology
- RNP 0.1 scenario
- Appendix

Scope of this document

- This work is based on the analysis of the attached sources and on interviews performed by L.E.K. in order to update the previous Inter-regional SBAS for Africa (ISA) CBA

- This report includes:
  - summary of the outcomes of Inter-regional SBAS for AFI CBA update*
  - comparison with previous results
  - explanation of the methodology used and of the value added by ISA and sources used

- In order to prepare this report L.E.K. has:
  - improved the methodology of the previous CBA via secondary sources as well as interviews to key industry players
  - updated inputs of previous CBA esp. on most critical data (e.g., African fleet, overall movements)
  - validated the model and gathered industry players feedback

Note: * The CBA considers the delta from the base line scenario which is Baro-VNAV without SBAS and Countries included represent 84% of nominal GDP

Source: L.E.K. analysis

We have delivered an update of the existing ISA CBA, mainly by improving the methodology, updating the data and providing a more solid and usable model

Improved methodology

- By leveraging our experience in modelling, we identified the weaknesses of previous methodology, suggesting improvement actions
- We proposed new approaches for both costs and benefits assessment

Updated data and statistics

- Through both primary and secondary research we have updated old data with new figures
  - Support from relevant institutions is key
- Model timeline have been updated with latest developments (to include 30 years, 2011-2041, timeframe)

More solid and usable tool

- Increase reliability of the tool via strong proof-making exercises
- Increase flexibility and maintainability
- Increase ease of use of the CBA

Inter-regional SBAS for AFI CBA update

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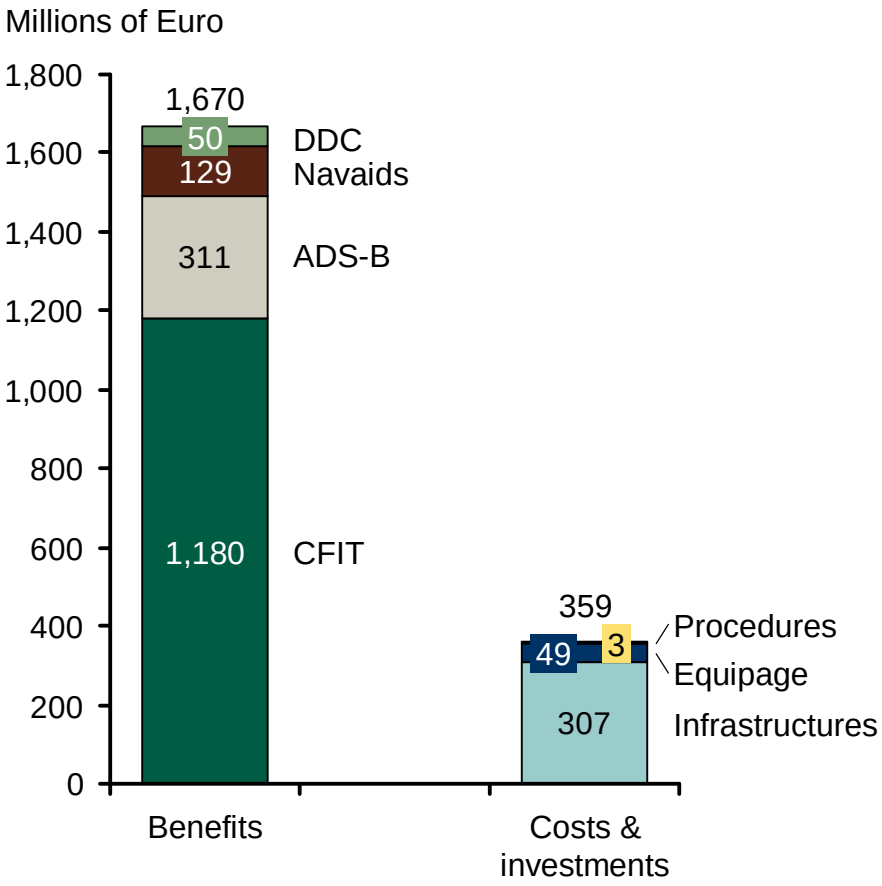
For the African aviation ISA benefits will amount to c. €1.7b, with respect to required investments of c. €359m

Cumulated undiscounted benefits and costs & investments (2011-41)



Benefits

- ISA will provide a series of benefits to the African aviation industry in terms of:
  - increased safety thanks to the reduction of CFIT occurrence
  - ADS-B system improvement
  - traditional navigational aids phasing out
  - DDC occurrence limitation

Costs & investments

- ISA deployment will require a series of expenditures:
  - ground infrastructures
  - aircraft equipage
  - airport procedures

Source: L.E.K. interviews and analysis

The methodology is logical and largely shared within the industry

- In the base case 100% penetration of LPV procedures on IFR landings is reached by 2020
- 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 and it takes ten years to complete the process according to Eurocontrol stated strategy
- 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
- Eurocontrol is in favour of EGNOS and believes the main benefit is in added, not quantifiable, safety

With a “top down” approach benefits and investments can be allocated to the relevant stakeholders

	Stakeholders in Aviation				
	Airlines	**General Aviation operators**	**Airports**	**ANSPs**	**Other Public***
Benefits					
DDC probability reduction	79%	19%	2%		
CFIT probability reduction					100%
ADS-B improvement	81%	19%			
Navaids phasing out			72%	28%	
Investments					
Aircraft equipage	81%	19%			
Airport procedures			50%	50%	

Note: * Other Public refers to the public entity which is the only one assuming primary responsibility of people life and of hull loss both reimbursed by insurance companies

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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	

Source: L.E.K. interviews and analysis

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

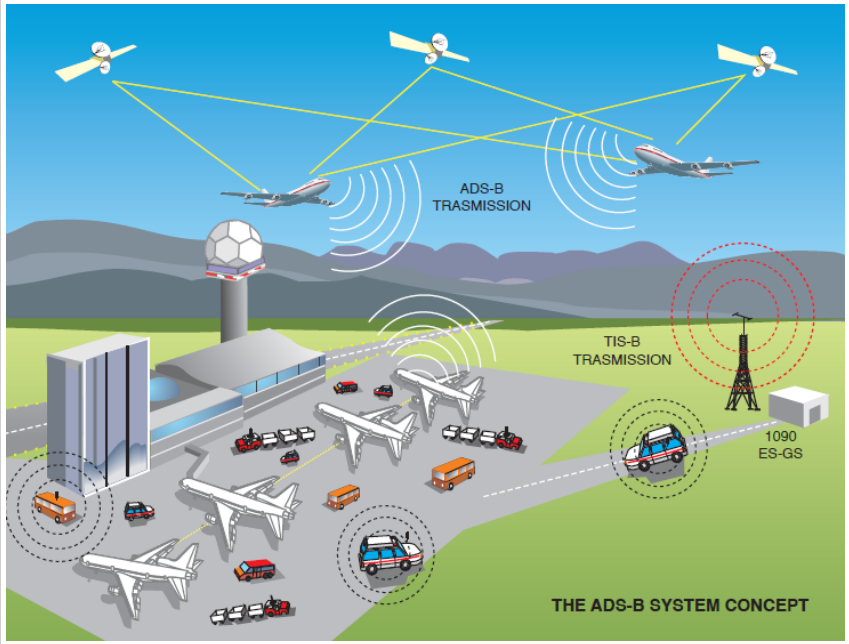
"…ISA will have an extremely positive impact on flight safety, determining a 100% CFIT avoidance …"
South African Airways, PBN Specialist

Source: L.E.K. interviews and analysis

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 …"
>
> ASECNA, Conseiller technique du Directeur de l'Exploitation

Source: L.E.K. interviews and analysis

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 …"

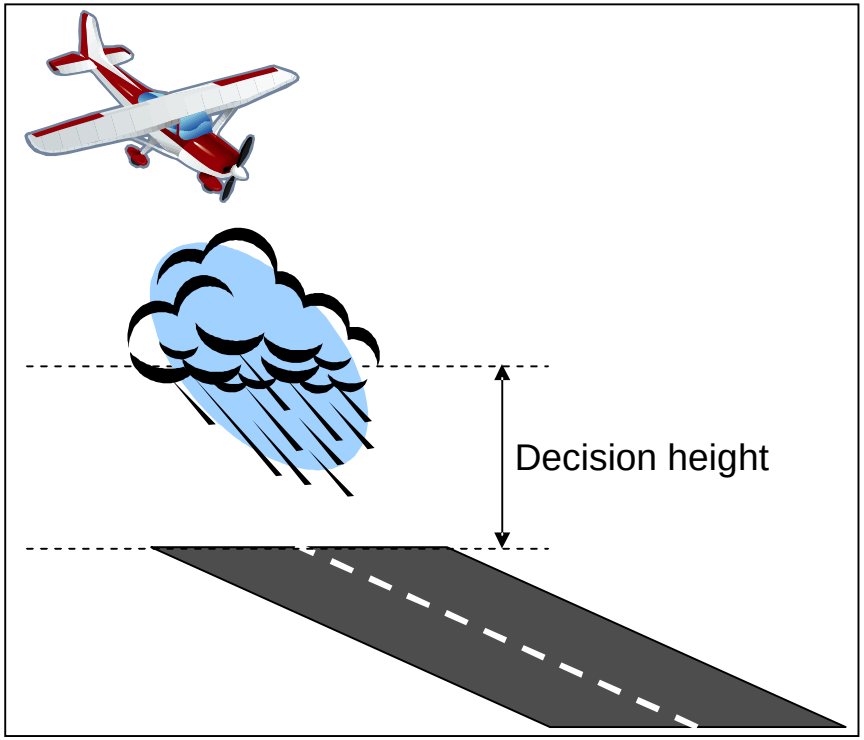
  ASECNA, Conseiller technique du Directeur de l'Exploitation

Source: L.E.K. interviews and analysis

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

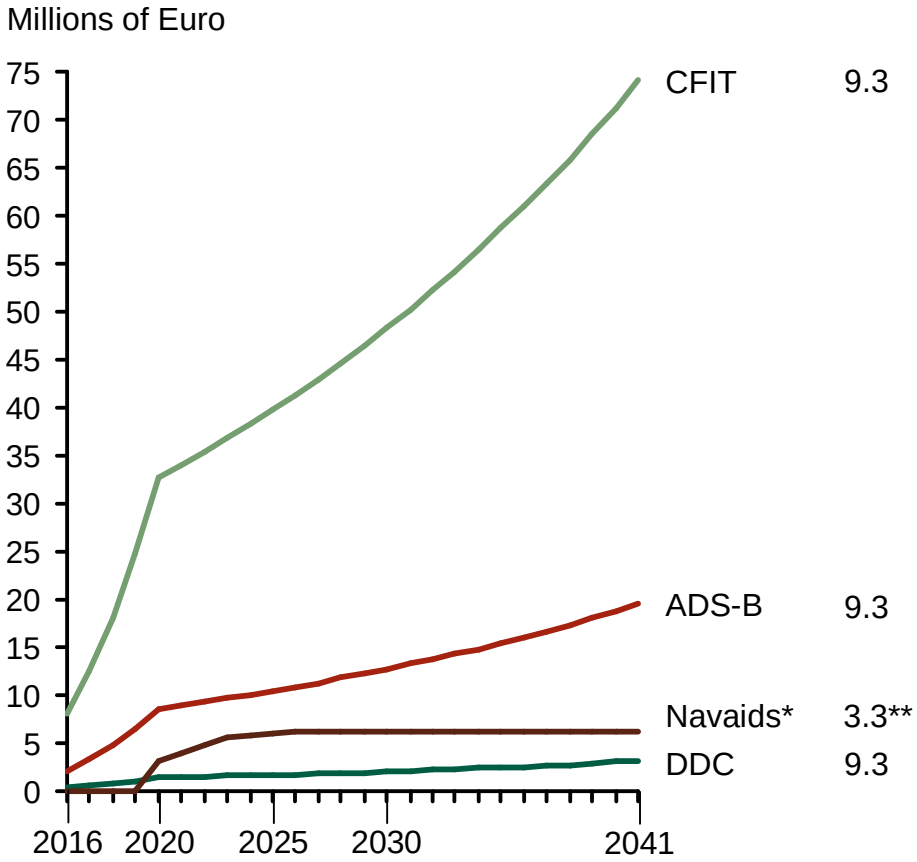
- ISA allows for SBAS-based Approaches with Vertical Guidance (APV), which enable lower minima

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

Source: L.E.K. interviews and analysis

In L.E.K. model 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

L.E.K. ISA undiscounted benefits YoY evolution (2016-41)



Note: * VOR and NDB; ** CAGR% 2020-41

- The avoidance of CFIT constitutes the greatest benefit of ISA

  "…Safety related benefits represent the most relevant advantage of ISA adoption …"
  ICAO, Regional Officer CNS

- 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

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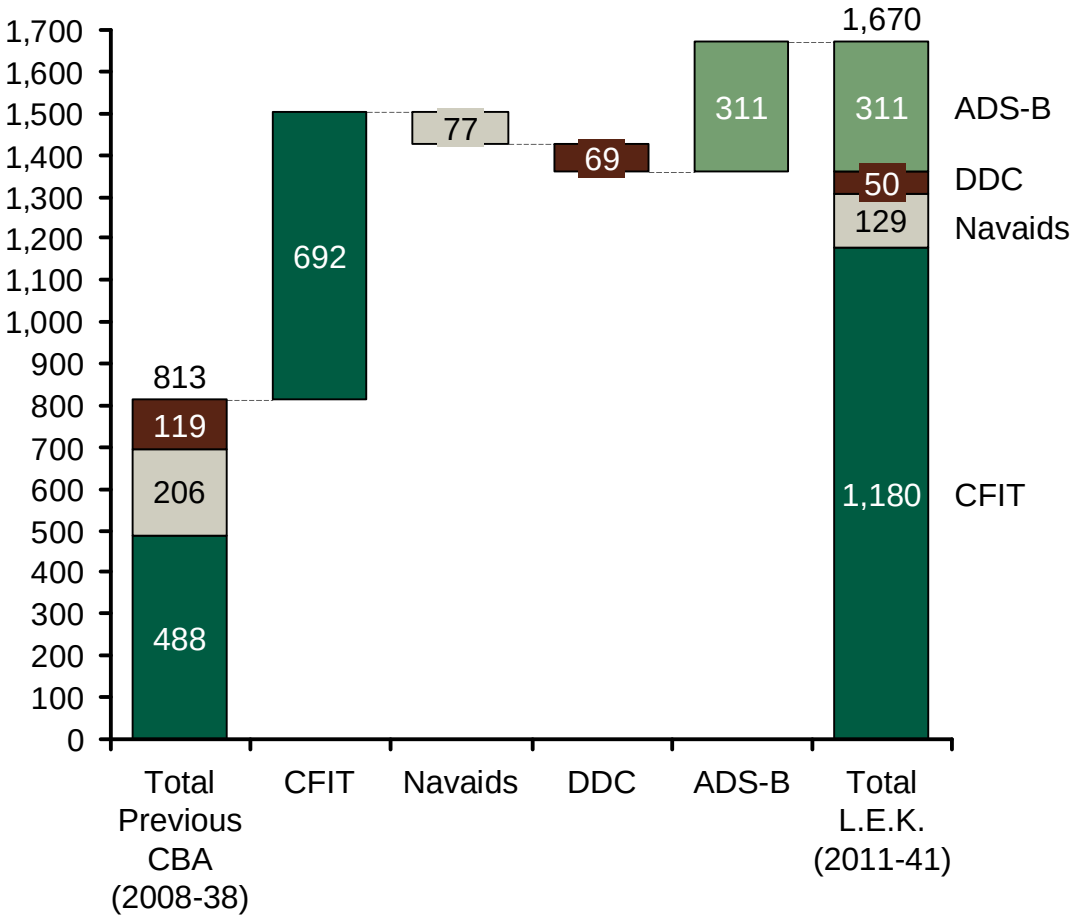
In the base scenario, L.E.K. undiscounted benefits estimate is c. €0.9b higher than the previous CBA, due to CFIT benefit increase and inclusion of the ADS-B benefit

Comparison of undiscounted benefits on a 30 years timeframe

Millions of Euro



Source: L.E.K. interviews and analysis

- L.E.K. undiscounted benefits are equal to c.€1.7b, increased by c.€0.9b as compared to the previous CBA
  - CFIT benefits have been increased of c.€692m
  - Navaids and DDC benefits have decreased by c.€77m and c.€69m respectively
  - in addition to the previous CBA L.E.K. has also considered the marginal benefits brought by ISA to ADS-B system

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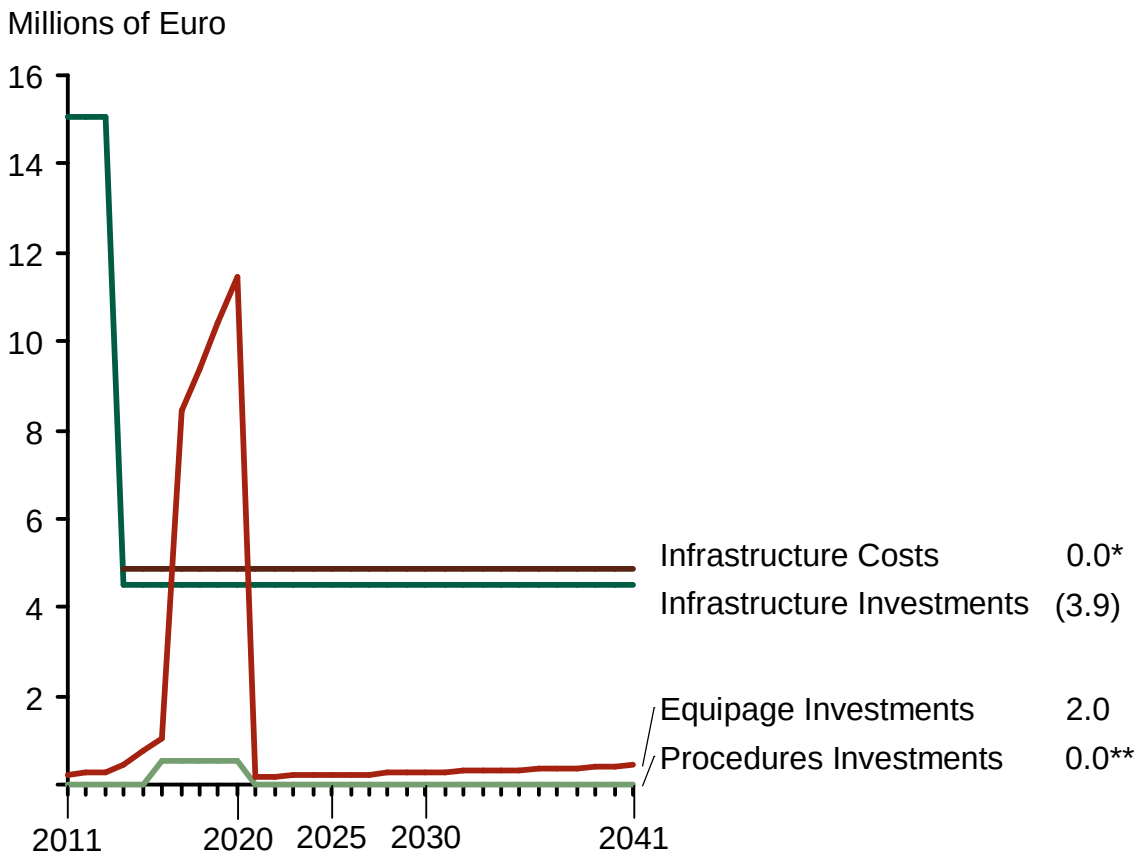
ISA will require to equip aircrafts with SBAS receivers, update airports' procedures and install and operate REMs and RIMSs

	Aircraft equipage	Airport procedures	Ground infrastructure deployment and maintenance
Graphical support			
Context description	l SBAS receivers require an update of GPS or multi-mode receivers thus being enabled to receive the signal l 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 …" South African Airways, PBN Specialist	l 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 …" ASECNA, Conseiller technique du Directeur de l'Exploitation	l 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 …" Eurocontrol, Technical Manager

Source: L.E.K. interviews and analysis

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

L.E.K. 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 …"
  ICAO, Regional Officer CNS

- 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^

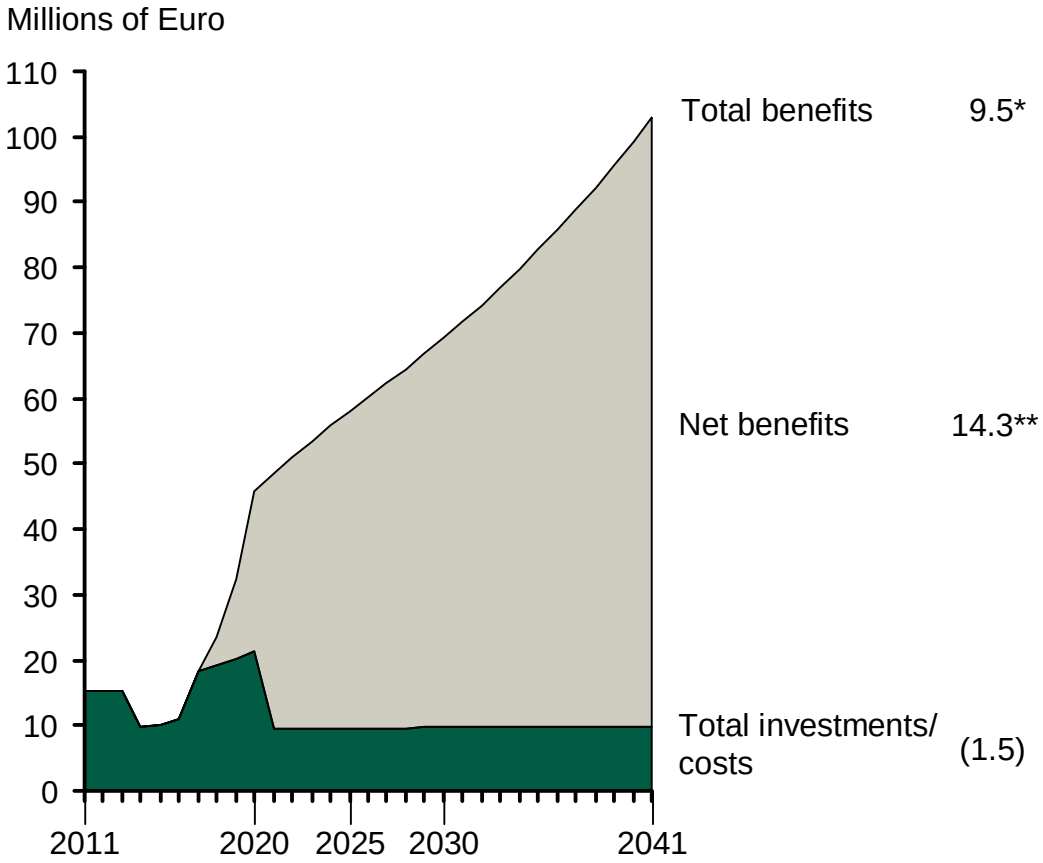
- Procedures costs^^ have been assumed to concentrate in 2016, when SoL signal will be certified

  "… Procedures for airports can be published only after SoL signal certification …"
  Eurocontrol, NAV infrastructure and GNSS activities Manager

Note: * 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
Source: L.E.K. analysis

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

L.E.K. ISA undiscounted Net benefits YoY evolution (2011-41)



Note: * CAGR% 2016-41; ** CAGR% 2018-41
Source: L.E.K. interviews and analysis

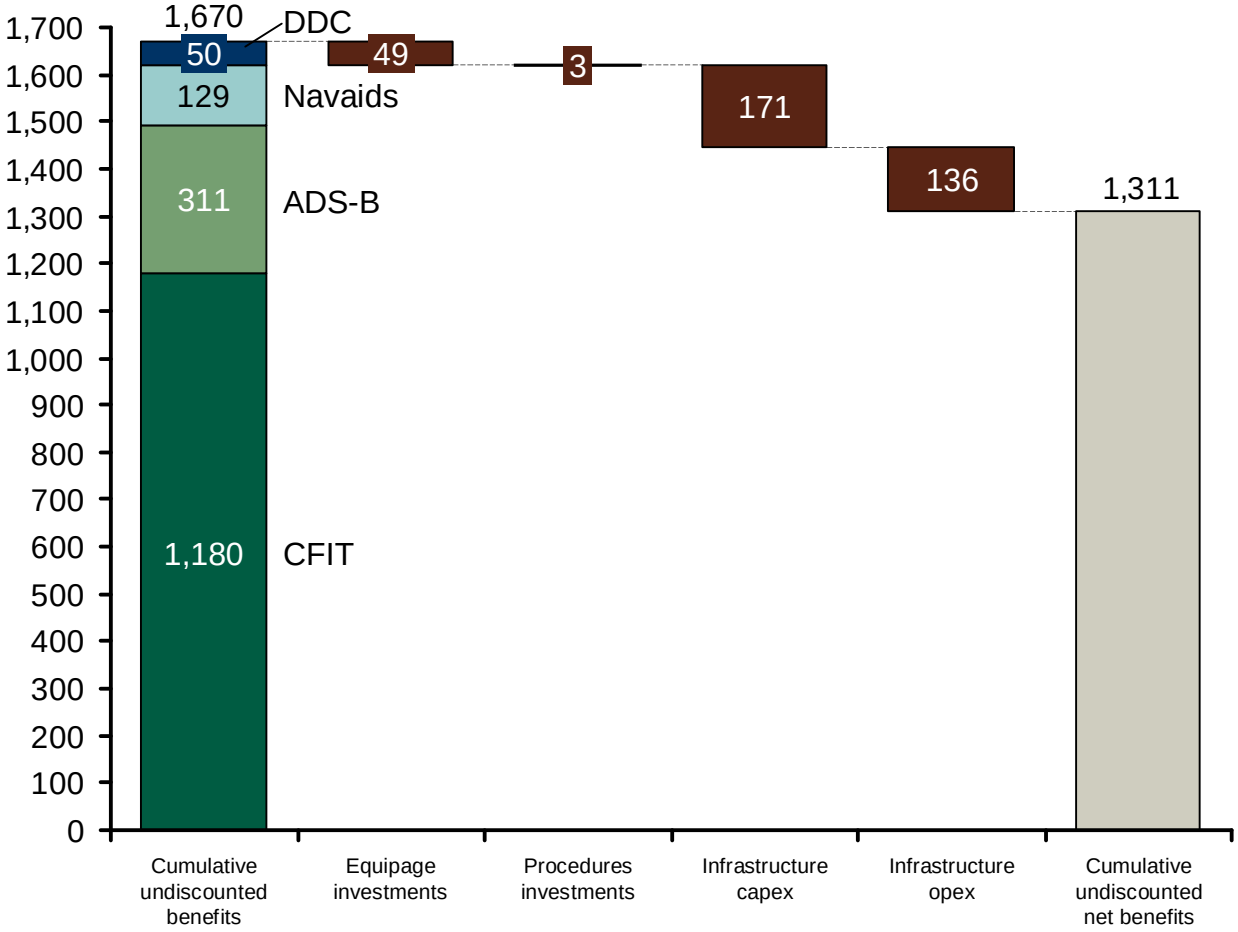
- ISA benefits are expected to exceed investments and costs associated to its implementation and operation
  - total benefits are estimated to amount to c. €102.9m in 2041, with a CAGR of 9.5% over the 2016-41 period
  - in the same year, total investments and cost are expected to be c.€9.8m, with a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

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

REMs and RIMSs constitute the most relevant ISA-related investments

L.E.K. ISA cumulative undiscounted net benefits on a 30 years timeframe (2011-41)

Millions of Euro



- Ground infrastructures have the highest impact on ISA potential benefits
- The same discount rate of previous ISA CBA, i.e. 8%, has been used

Discounted net benefits **211.1€m**

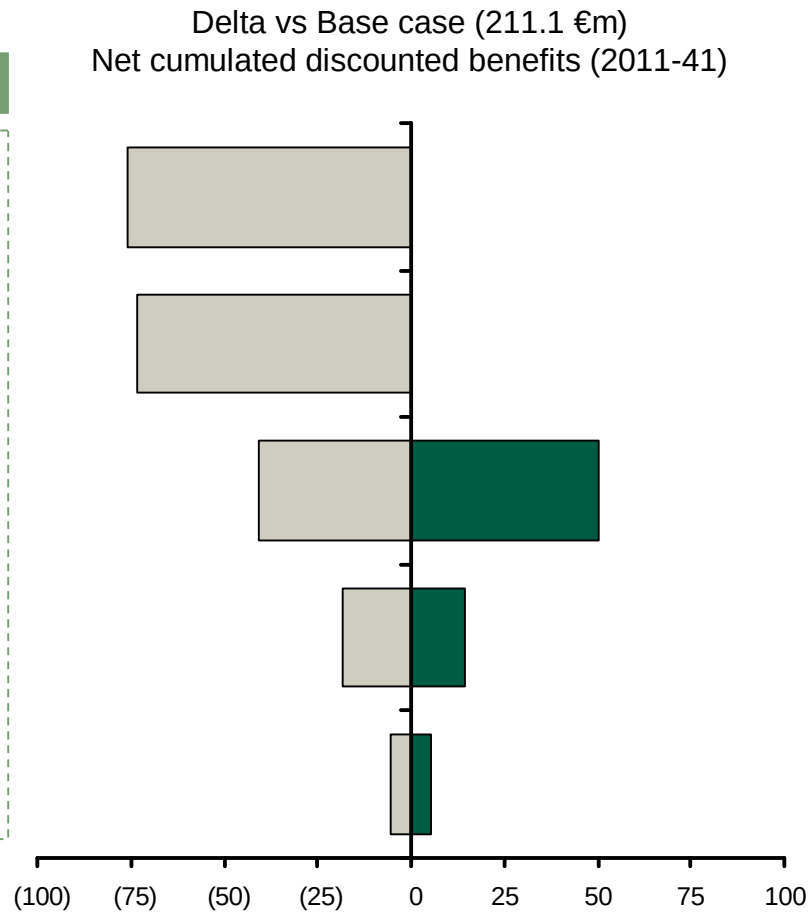
Source: L.E.K. interviews and analysis

Increasing Wacc and excluding IATA flights have the highest negative impact on benefits

L.E.K. model sensitivity analysis

Millions of Euro

	Worst case	Base case	Best case
WACC %	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



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

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

Adoption by air fleets and airports' procedures [%]

	ICAO adoption scenario	2020 adoption scenario	2025 adoption scenario
100% penetration of LPV procedures on IFR landings*	2016, with a 30% by 2010 and 70% by 2014	2020, with a PPT% constant increase from 2009 to 2020	2025, with a PPT% constant increase from 2009 to 2025

Base case

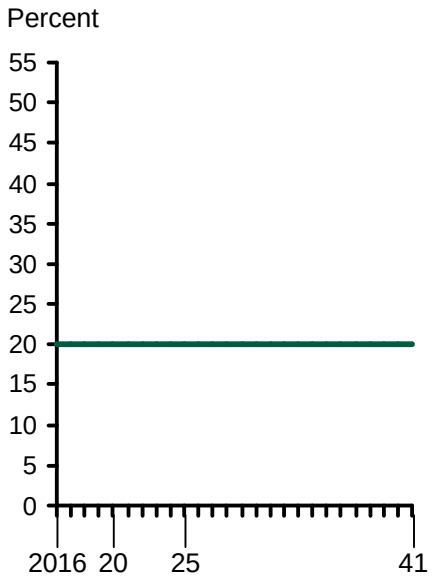
Note: * c. 90% of total landings
Source: L.E.K. analysis

… assuming different ISA market shares as compared to alternative technologies…

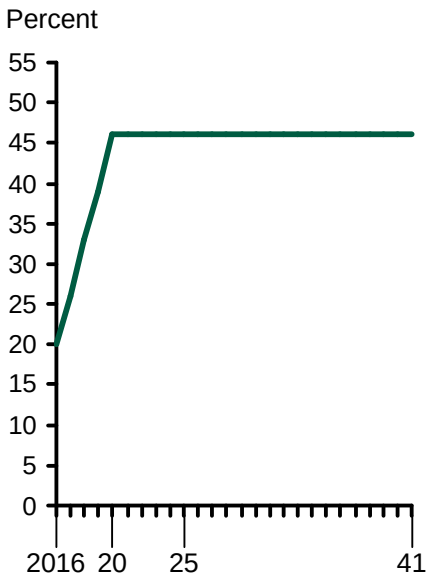
ISA market share according to different scenarios

100% penetration of LPV procedures on IFR landings

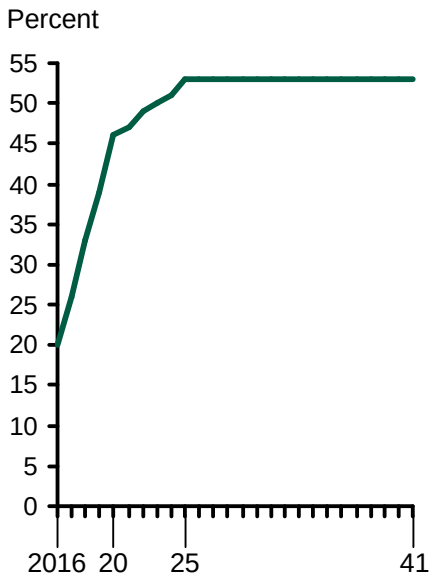
ICAO adoption scenario



2020 adoption scenario



2025 adoption scenario



Source: L.E.K. analysis

… and leading to different net benefits results

	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

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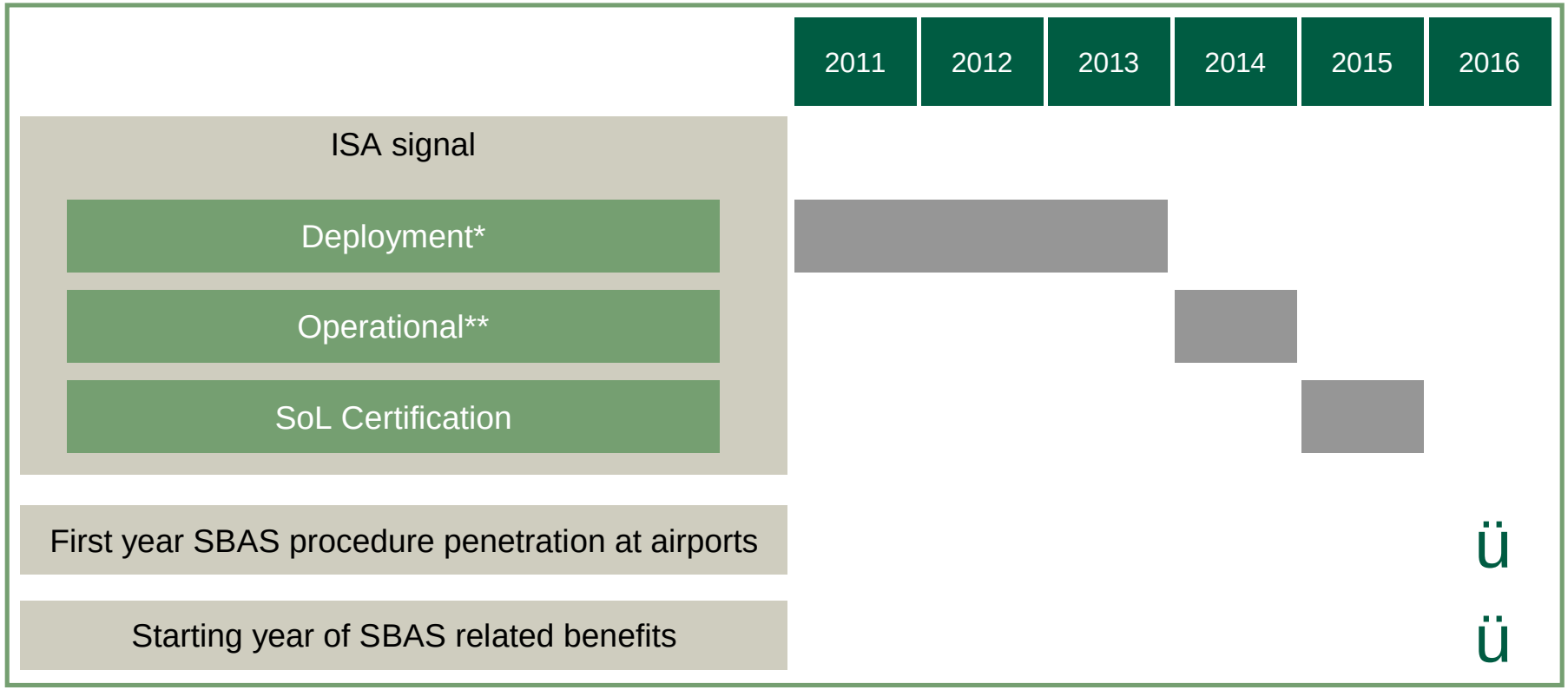
In our model we have considered all the important milestone and the following timeframe has been assumed



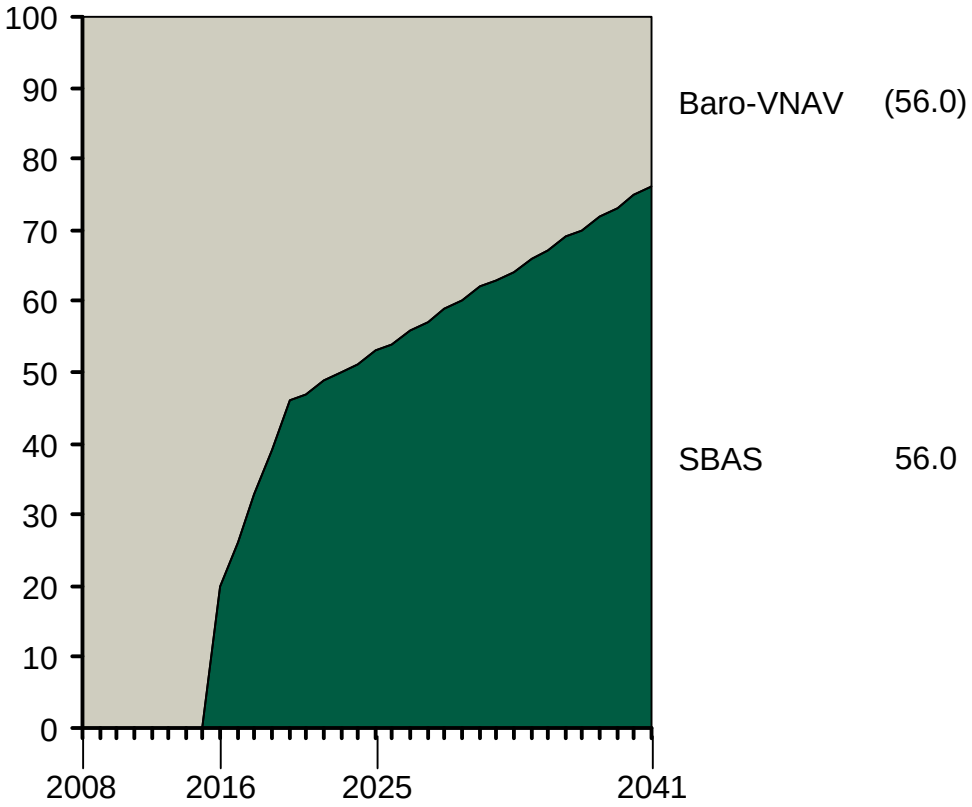
Note: * Start of infrastructure realization; ** Availability of SBAS Open Service
Source: L.E.K. interviews and analysis

Baro-VNAV competition has been considered in order to estimate ISA penetration in the AFI region

ISA vs Baro-VNAV market share evolution (2008-41)

• PPT (2016-41)

Percent



- GPS + Baro-VNAV is used to provide continuous vertical guidance and can be used to perform APV landings as an alternative to SBAS
- ISA compared to Baro-VNAV has two advantages:
  - some aircraft do not have certified and integrated systems to meet Baro-VNAV; for these aircraft, APV SBAS will be a good option
  - slightly lower minima

Source: L.E.K. interviews and analysis

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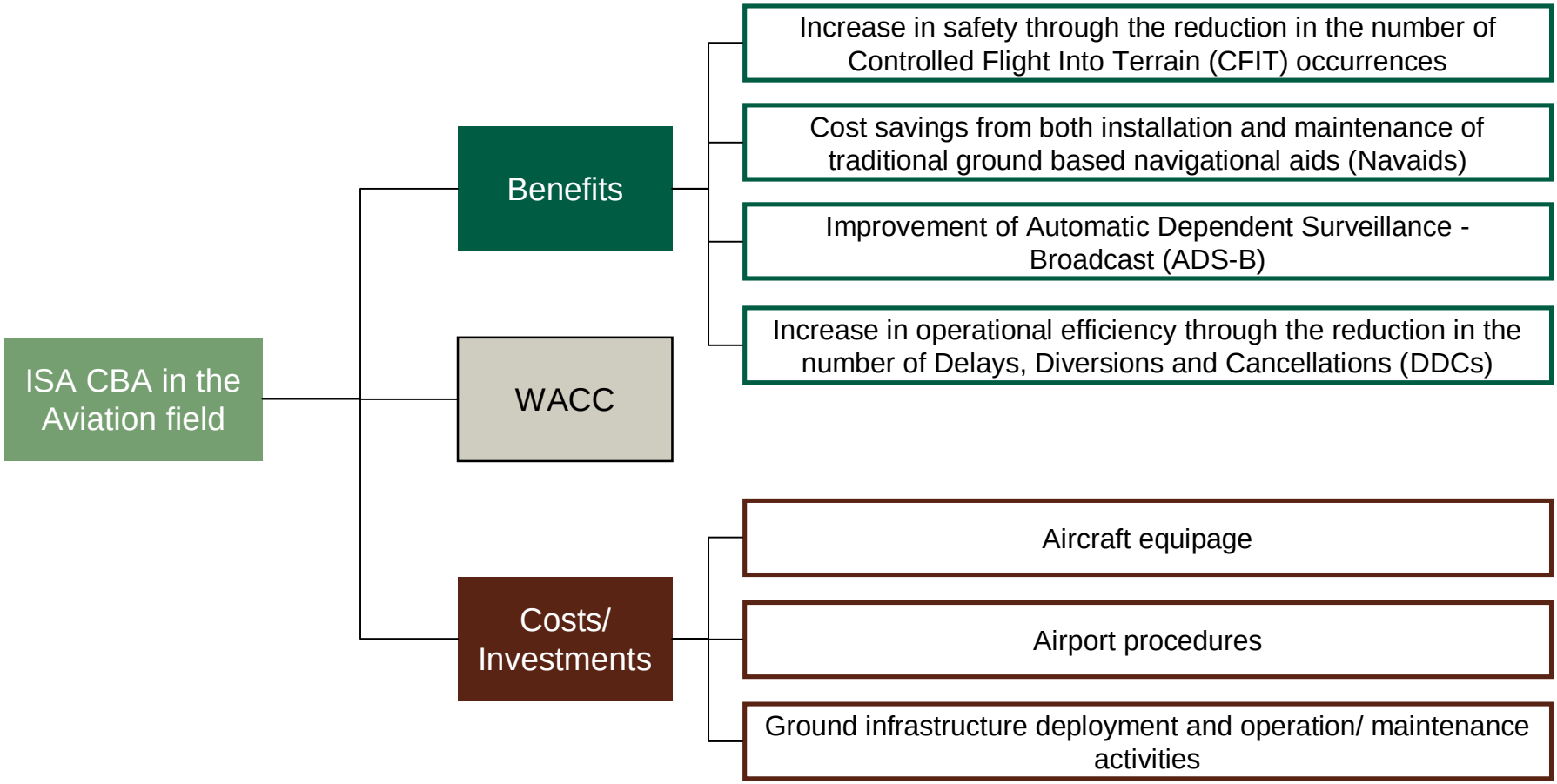
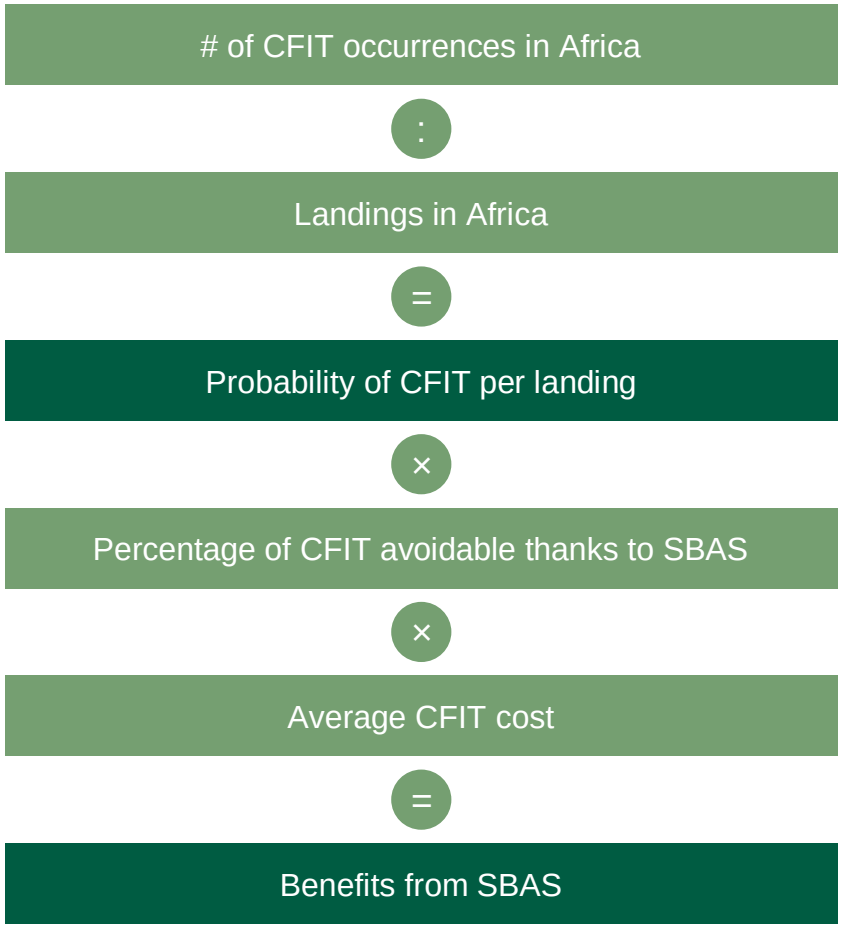
ISA is expected to guarantee higher safety and operational efficiency to the AFI region



Source: L.E.K. interviews and analysis

ISA is expected to increase flight safety, lowering the probability of occurrence of Controlled Flight Into Terrain (CFIT)

Yearly estimation of ISA safety related benefits



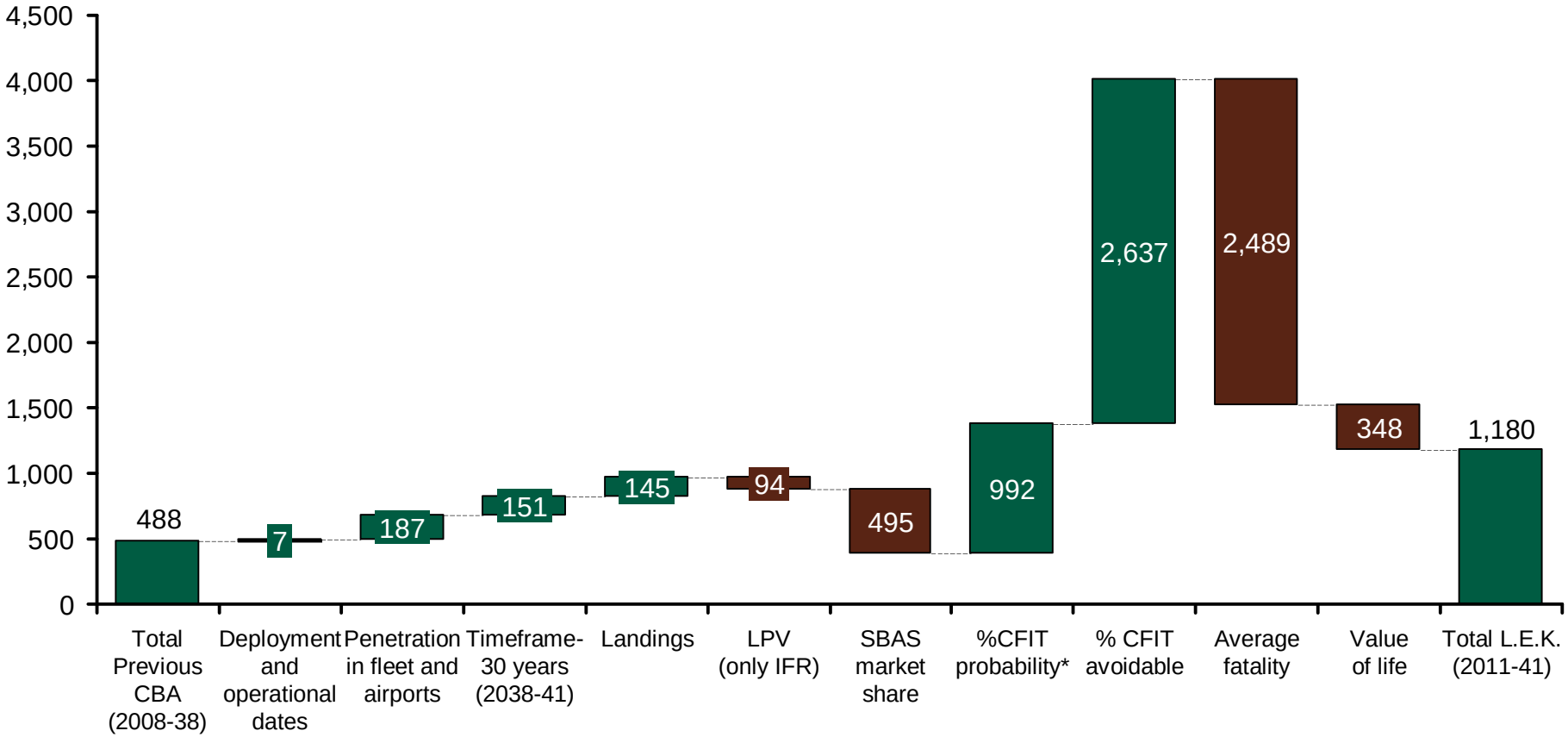
- Controlled flight into terrain (CFIT) describes a collision whereby an airworthy aircraft, under pilot control, inadvertently flies into terrain, an obstacle, or water
  - CFIT often occurs during aircraft descent to landing, near an airport and it is often caused by terrain being obscured by clouds
- CFIT total cost comprehends both human life costs and cost of hull loss

Source: L.E.K. interviews and analysis

CFIT benefit bridge

Comparison of undiscounted benefits on a 30 years timeframe

Millions of Euro

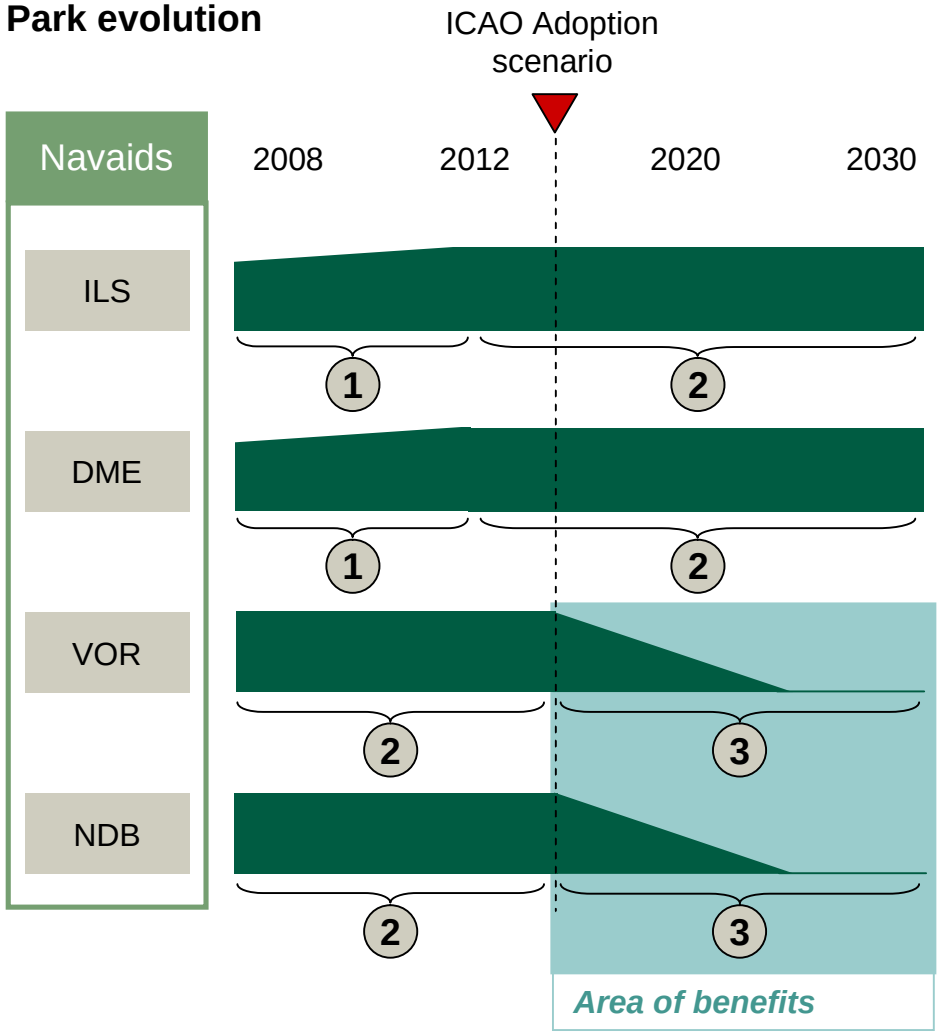


Note: * Updated according to the average number of CFIT occurrences in Africa (2005-08) from NTSB and correction of a calculation error made by the previous CBA

Source: L.E.K. interviews and analysis

From full LPV implementation date it is expected the phasing out of NDB and VOR navaids representing a ISA related benefit

Park evolution



1 Increase in population

- ICAO states that 18% of additional navaids must be installed between 2008 and 2012
- In this phase new navaids are considered to replace old ones in order to keep existing stock

2 Maintenance in population

- In this phase new navaids are considered to replace old ones in order to keep existing stock

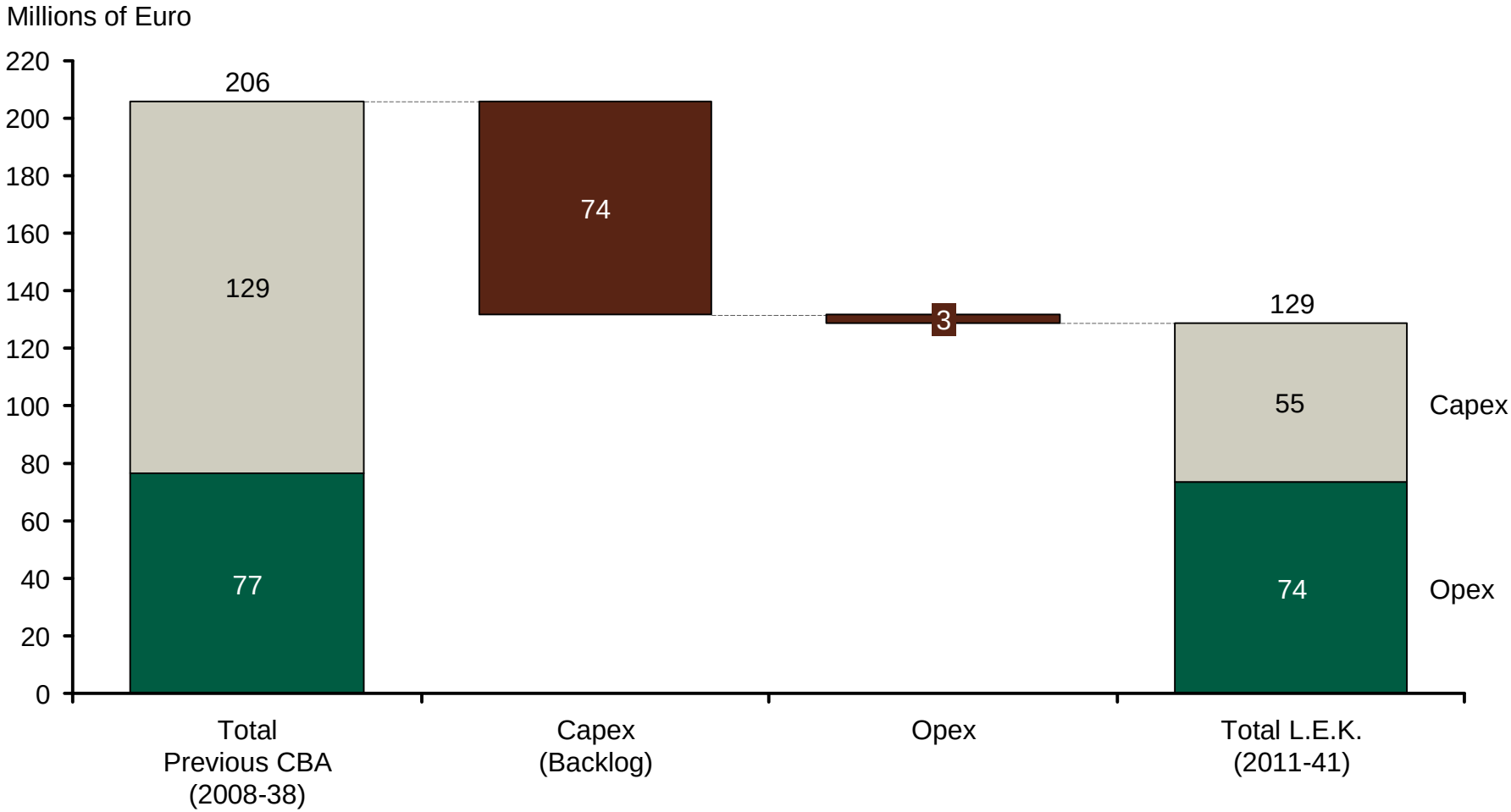
3 Phasing out in population

- In this phase old navaids are not replaced and additional working navaids are gradually phased out

Source: L.E.K. interviews and analysis

Navaids benefit bridge

Comparison of undiscounted benefits on a 30 years timeframe



Source: L.E.K. interviews and analysis

ADS-B system adoption is expected to determine significant benefits in terms of routes optimization, higher safety and enroute radars replacement

ADS-B related benefits	Strictly ISA-related	Methodology/ comments
Flight routes optimization Savings are based on efficiency through reduced separation standards that allow aircraft to climb to optimal altitudes much earlier, and to follow more efficient routes*	ü	Number of flights × Share of flights with no radar surveillance × Average number of minutes saved with optimized route × Average cost per minute = Total savings thanks to optimization
Higher safety Improved search and rescue as ADS-B can provide much better location information as to where an aircraft went missing	û	ADS-B benefits like higher safety and enroute radars replacement are not directly related to ISA, as GPS alone guarantees the achievement of such benefits "…Among ADS-B benefits, only route optimization can be directly referred to ISA, as only in this case integrity provided by the SBAS system is required …" ICAO, Regional Officer CNS "…The most important benefit related to ISA is route optimization …" ASECNA, Manager of the Air Circulation Bureau
Enroute radars replacement After ADS-B certification, no more enroute radar is expected to be deployed and a phasing out process will potentially take place	û	

Note: * Only marginal improvement of SBAS over GPS has been considered
Source: L.E.K. interviews and analysis

L.E.K. model does not incorporate ADS-B investments and costs, as they are not directly associated to ISA

GPS-based ADS-B

- ADS-B systems is planned to be implemented in Africa, exploiting GPS signal
  - "…The process of ADS-b adoption has already started and it is based on GPS signal …"
    ASECNA, Manager of the Air Circulation Bureau
- Ground infrastructures of ADS-B will be deployed independently from SBAS adoption
  - "…Ground based station supporting ADS-B will be realized in Africa also without SBAS systems …"
    ASECNA, Manager of the Air Circulation Bureau
  - "…The deployment of ADS-B infrastructure and the installation of specific avionics do not depend on SBAS adoption …"
    ASECNA, Conseiller technique du Directeur de l'Exploitation

Marginal benefits of ISA-based ADS-B

- The L.E.K. CBA incorporates only the marginal benefits of ISA-based ADS-B
  - "…In my opinion the introduction of a SBAS system in the ADS-B, could provide an increase of benefits amounting to c. 35% …"
    ASECNA, Manager of the Air Circulation Bureau
  - "…The development of a SBAS-based ADS-B could determine an increase in benefits of c.20% with respect to a traditional GPS-based ADS-B …"
    ASECNA, Conseiller technique du Directeur de l'Exploitation

Being not directly related to ISA implementation, ADS-B investments and costs were not included in the L.E.K. model

Source: L.E.K. analysis

ISA allows a reduction of DDC probability of occurrence, with significant savings for both airports and airlines

DDC benefits estimation model

Total aircraft landings

Probability of Delays, Diversions and Cancellations
- Share of Delays
- Share of Diversions
- Share of Cancellations

Share of DDCs avoidable thanks to ISA

Cost savings

Impacting variables

ISA effectiveness against DDCs
Adoption by airport
Adoption by airlines

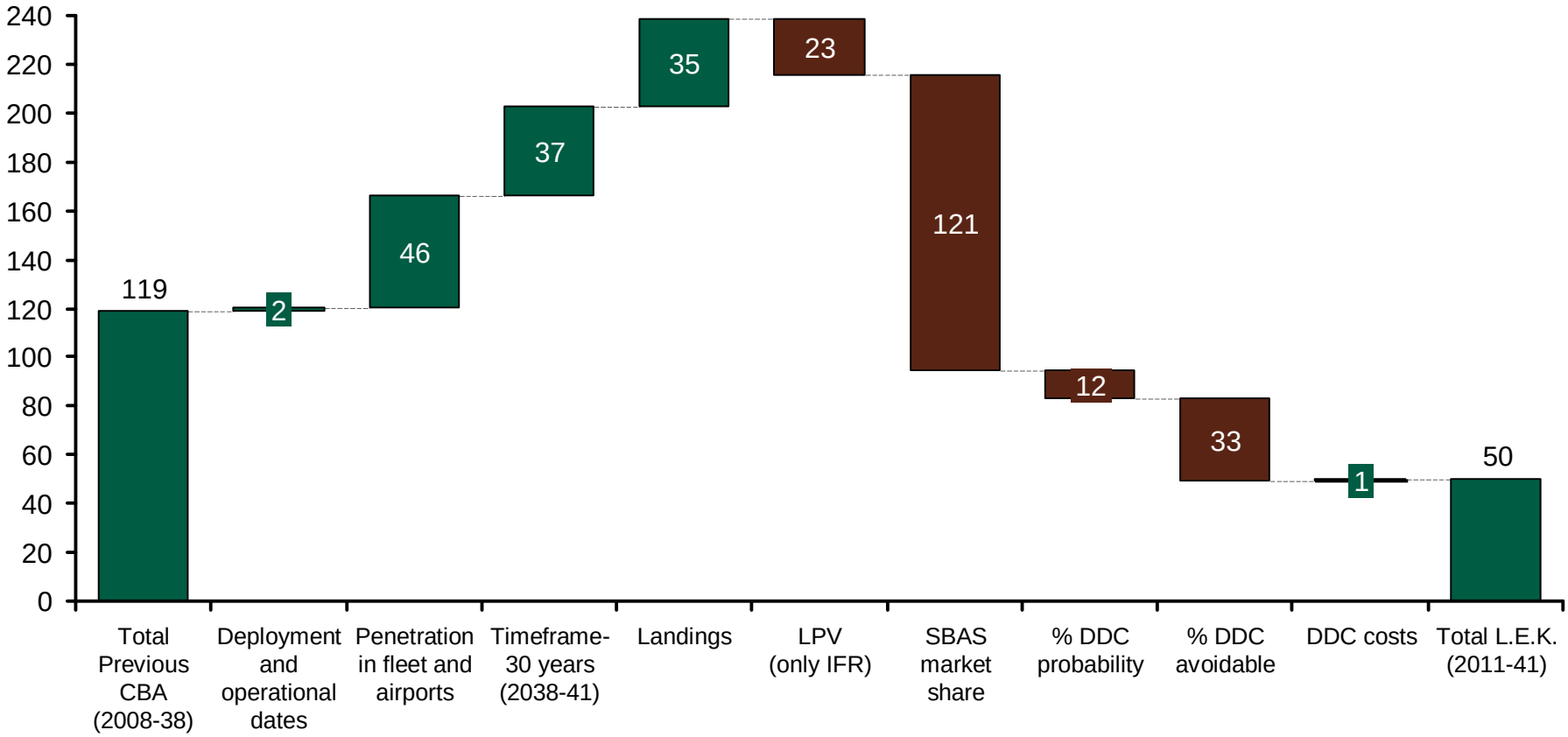
Average DDC cost
- Fuel
- Crew
- Maintenance
- Aircraft ownership
- Average passenger time value

Source: L.E.K. analysis

DDC benefit bridge

Comparison of undiscounted benefits on a 30 years timeframe

Millions of Euro



Source: L.E.K. interviews and analysis

Aircraft equipage costs comprehend both retro-fit costs and forward-fit ones

Equipage cost estimation model

- Retro-fit costs
  - =
  - SBAS receiver
  - \+ Integration
  - \+ Installation
  - \+ Crew training
  - \+ Documentation
  - \+ Certification
  - ×
  - Number of aircrafts
- \+
- Forward-fit Cost
  - =
  - Crew training
  - \+ Other cost
  - ×
  - Number of aircrafts

Source: L.E.K. interviews and analysis

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Airport procedures costs, related to new landing instructions to be defined by ANSP are estimated to be c.€24K per runway

Airport procedures costs estimation model

Airport procedures costs

=

Number of runways

×

Procedure publishing cost

- Single procedure publishing costs are estimated to be c.€24K per runway
  - procedure publishing is performed by national ANSP, who is in charge of defining instructions to be observed during landing process

"… Procedures costs don't vary significantly in Africa if compared to what is in Europe or in USA because the labour force is coming from this two continents and the instruments are the same …"
Pildo Labs, Manager

- In order to define a SBAS based landing procedure, ANSP performs a series of analyses
  - obstacle clearance surface
  - obstacle evaluation area
  - obstacle identification surface
  - glide-path qualification surface

Source: L.E.K. interviews and analysis

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Infrastructure costs are related to both REMs and RIMSs and comprehend deployment and operational expenditures

REMs and RIMSs costs estimation model

REMs costs	RIMSs costs
=	=
Number of REMs	Number of RIMSs
×	×
Capex	Capex
Unit cost	Site surveys, equipment, deployment and qualification, VSAT communications network, upgrade of calibration aircraft, safety case and training and regulatory issues
+	+
Opex	Opex
Maintenance and data processing fee	ISA staff, communications, maintenance, administration and ISA service provider fee recovery

Source: L.E.K. analysis

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RNP stands for Required Navigation Performance and is part of ICAO's new Performance Based Navigation (PBN)

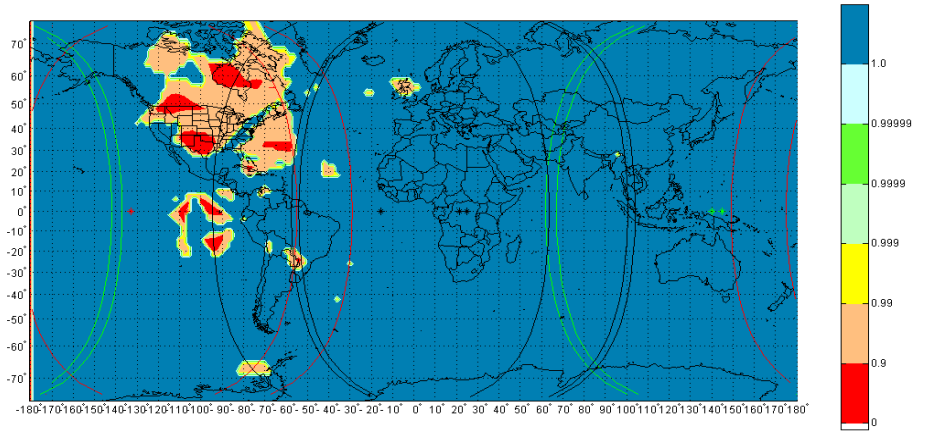
- The figure added after 'RNP' refers to the 95 % accuracy requirements in Nautical Miles, e.g. RNP 2 has a 95% navigation accuracy specification of 2 NM
- RNP and the older RNAV (area navigation) specifications overlap (RNAV 5 is equivalent to RNP 5)
- For an aircraft to be RNP capable it requires onboard alerting and monitoring equipment in addition to GPS avionics
  - new large jet aircrafts are forward fitted with RNP systems
  - RNP systems have a significant cost for retrofitting
  - regional airlines that operate older, smaller jets are not yet interested in upgrading to RNP (they continue to operate using RNAV procedures)

The ICAO PBN requirements (Resolution A36-23) implies that RNP is sufficient for APV landings

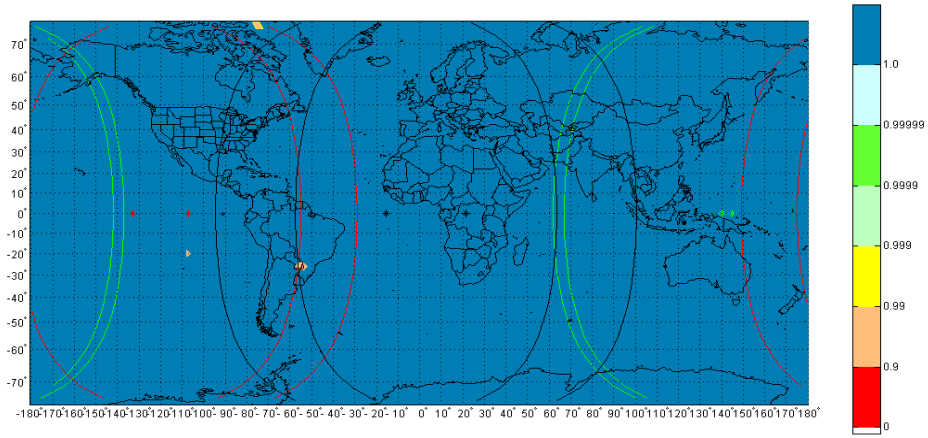
- Only RNP includes approach operations, RNAV mostly concerns en-route phases of flight
- An RNP AR (authorisation required) APCH requires a accuracy of 0.3-0.1 NM
  - i.e. an 95% horizontal accuracy of ~556 m down to ~185 m
  - and Baro-VNAV for vertical guidance
- Airbus and SAA still consider these as NPA (and that only SBAS will allow APV)
- We suspect confusion has arisen since it depends on the equipage of the aircraft
  - a simple GPS receiver onboard plus Baro-VNAV will not allow APV
  - a sophisticated RNP-capable FMS + Baro-VNAV will allow APV (to be verified)

An experiment on RNP 0.15 availability was conducted on 29 April 2008

RNP 0.15 Availability on 29 April 2008 from 1014 to 1214 Zulu



Service Availability for HAL = 0.15 NM using GPS+RAIM Equipment



Service Availability for HAL = 0.15 NM using SBAS Equipment

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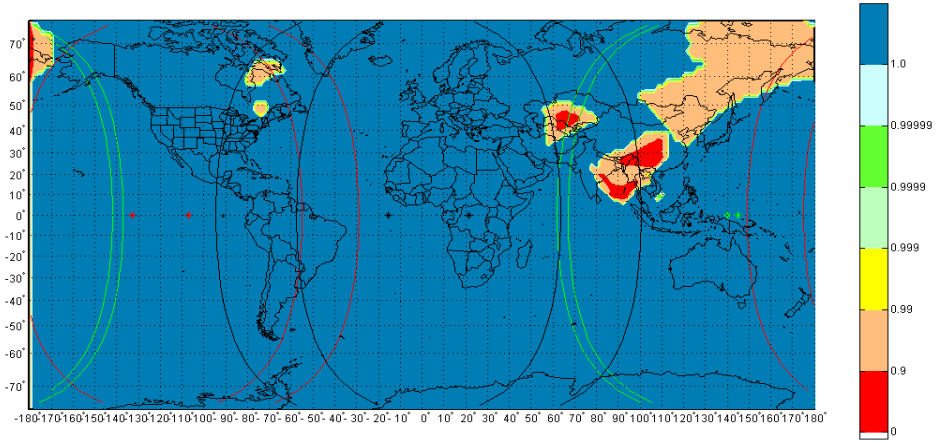
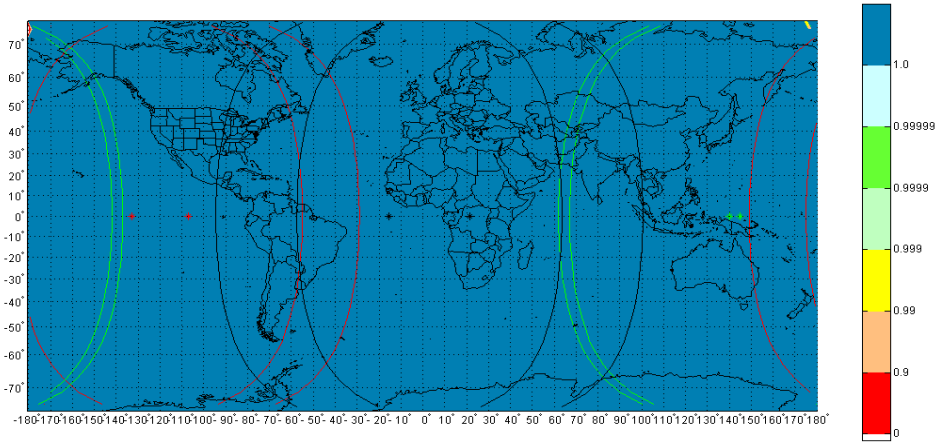
An experiment on NPA availability was conducted on 7 June 2008

NPA Availability on 7 June 2008 from 1751 to 2005 Zulu



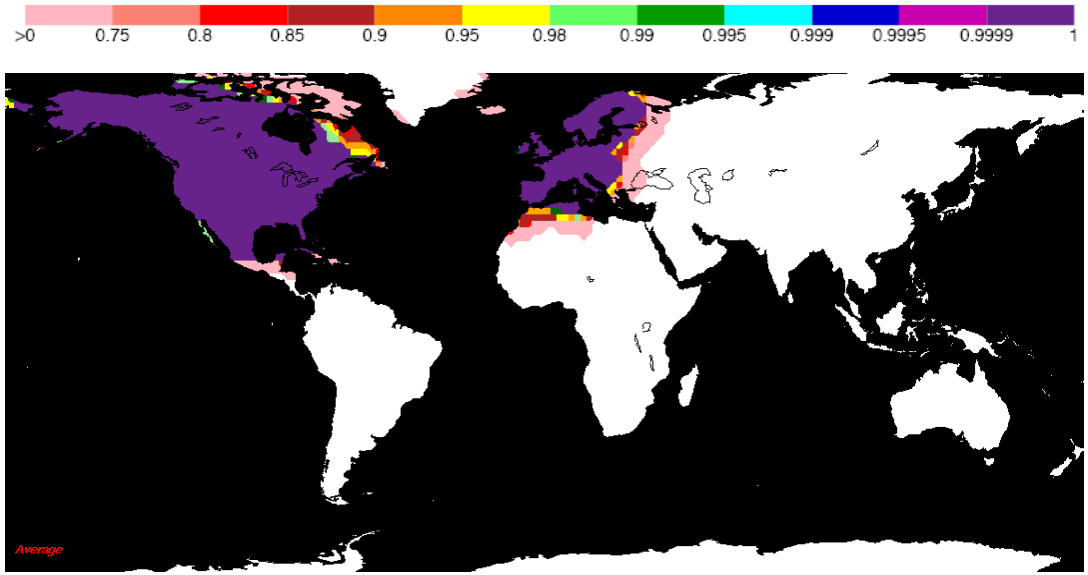
Service Availability for HAL = 0.3 NM using GPS+RAIM Equipment



Service Availability for HAL = 0.3 NM using SBAS Equipment

An experiment on APV availability was conducted on 29 April 2008

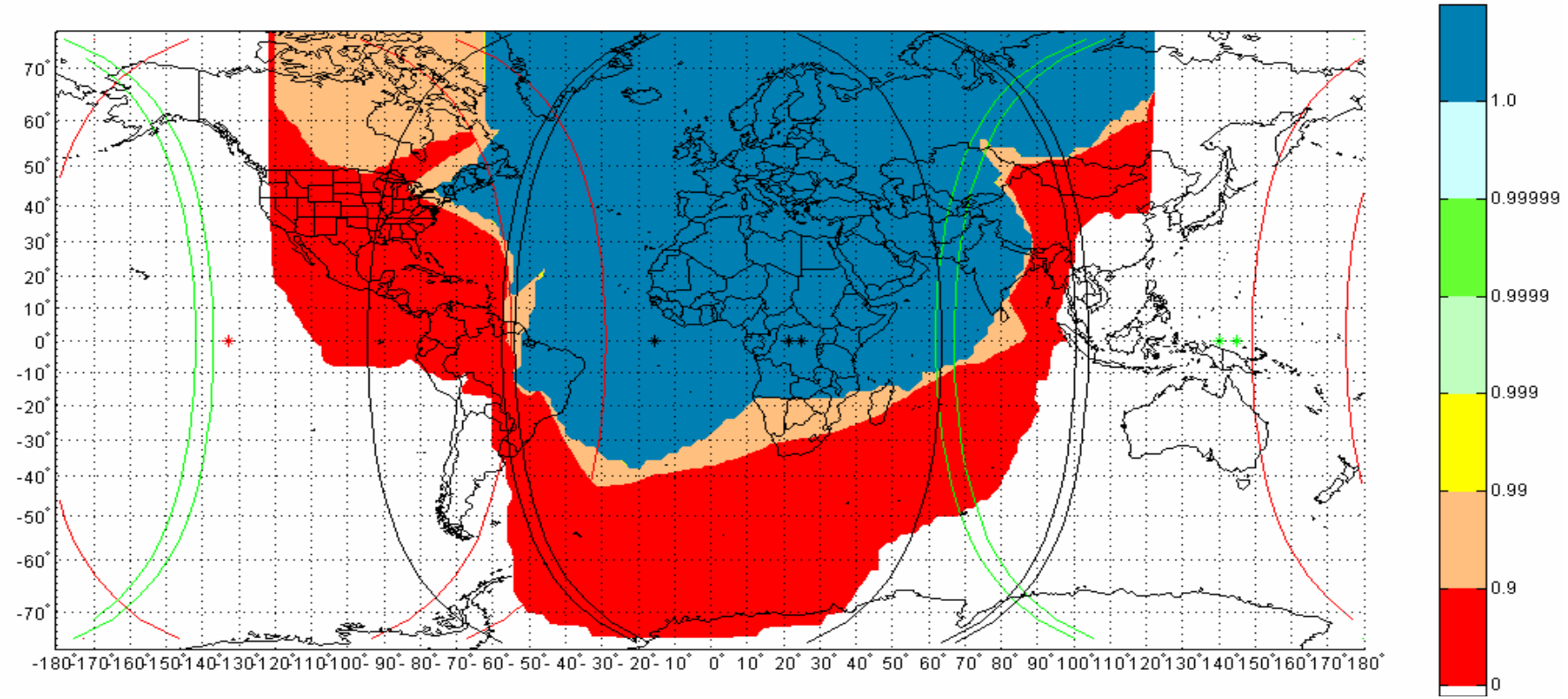
APV-I Availability on 29 April 2008 from 1014 to 1214 Zulu



- With GPS alone, service availability for Horizontal Alarm Limit can be as low as 90% over large geographic regions (depending on the GPS satellite that has failed)
- By using SBAS, the service availability (horizontal accuracy) can be improved back to 100% even if a GPS satellite fails (except for some very small areas)
- EGNOS capability is already available over most of Africa

EGNOS RNP 0.1 service availability over AFI was measured on 29 April 2008 (10:14- 12:14 Zulu)*

Enhanced NPA service achieved through SBAS over Africa down to 20 deg. South Lat



Note: * Removing MT27 contribution, results prepared by MITRE for FAA, presented at ICAO NSP

EGNOS RNP in AFI could guarantee a series of advantages

- Will improve GPS service availability within RNP from 90% to 100%
- It is estimated that an additional 5 RIMS in Southern Africa will be sufficient to extend coverage over the whole continent (with modification of EGNOS Message 27)*
- Will allow enhanced NPA (but NOT APV)
- Will this allow landing procedures based on RNP to be designed with smaller separation minima?
  - since the confidence in the service availability is greater?
  - thereby leading to customised curved approaches which can gain airlines significant savings in approach distances (time and fuel)
- This can be explored during further interviews with ANSPs and airlines

Note: * This does not correspond to SBAS coverage, and not nearly the equivalent to ISA (full SBAS) RNP

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During its assignment, L.E.K. has conducted a total of 44 interviews with main ISA stakeholders

ISA Stakeholders (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

L.E.K. has reviewed a comprehensive list of 19 secondary sources (1/2)

Title	Author	Date
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

L.E.K. has reviewed a comprehensive list of 19 secondary sources (2/2)

Title	Author	Date
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

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Preliminary benefits results comparison of the three different scenarios based on full LPV implementation date hypotheses

	ICAO adoption scenario	2020 adoption scenario	2025 adoption scenario
Benefits related to DDC			
Discounted	5.1€m	10.4€m	10.6€m
Undiscounted	22.8€m	50.2€m	54.6€m
Benefits related to CFIT			
Discounted	119.5€m	245.2€m	249.9€m
Undiscounted	537.1€m	1,180.1€m	1,283.8€m
Benefits related to Navaids			
Discounted	38.1€m	26.3€m	15.8€m
Undiscounted	153.6€m	128.7€m	97.7€m
Benefits related to ADS-B			
Discounted	31.5€m	64.6€m	65.9€m
Undiscounted	141.6€m	311.1€m	338.4€m
Total Benefits			
Discounted	194.2€m	346.5€m	342.1€m
Undiscounted	855.1€m	1,670.1€m	1,774.5€m

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Preliminary costs results comparison of the three different scenarios based on full LPV implementation date hypotheses

	ICAO adoption scenario	2020 adoption scenario	2025 adoption scenario
Equipage costs			
Discounted	2.6€m	22.1€m	22.5€m
Undiscounted	6.0€m	48.9€m	50.6€m
Procedures costs			
Discounted	0.7€m	1.4€m	1.4€m
Undiscounted	1.2€m	2.8€m	3.2€m
Infrastructure costs			
Discounted	111.9€m	111.9€m	111.9€m
Undiscounted	307.3€m	307.3€m	307.3€m
Total Costs			
Discounted	115.3€m	135.5€m	135.8€m
Undiscounted	314.5€m	359.0€m	361.1€m

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CBA general inputs

Input	Value	Source
Landings	• In 2008: c.1.3m landings	ACI
	• CAGR% (2008-41): 4.1%	
	• IFR vs VFR: 90.4% vs 9.6%	SAA, Garmin
	• CA vs GA: 81% vs 19%	ACI
Airport runways	• In 2008: 1,101	Jeppesen
	• IFR vs VFR: 23% vs 77%	Jeppesen
Fleet	• In 2008 CA (Jet 816 and Turboprop 849) and GA (Jet 195 and Turboprop 463)	Ascend
	• CAGR% (2008-41): 4.1%	L.E.K. estimate
LPV penetration	• 100% in 2016, with a 30% by 2010 and 70% by 2014	ICAO

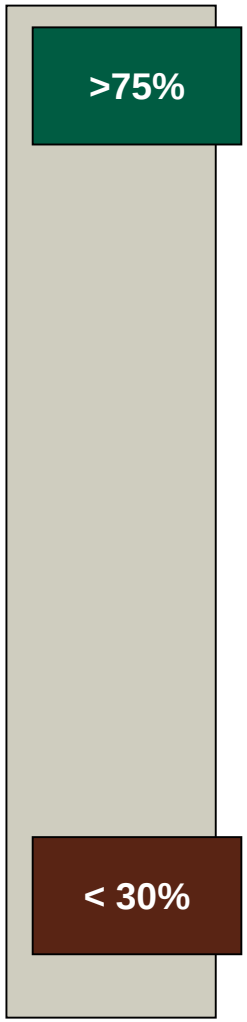
Source: L.E.K. interviews and analysis

CBA CFIT inputs

Input	Value	Source
% of CFIT occurrence	• 0.00032%	NTSB
EGNOS effectiveness against CFITs	• 87.3%	SAA, FAA, NTSB, FSF, Jet Pro
Average CFIT cost	• Average fatality per accident: 10.75 persons	NTSB
	• Statistical value of life: €173,764	Environmental Protection Agency
	• Average hull loss: €10.75m	Eurocontrol

Source: L.E.K. interviews and analysis

There are mainly two discordant opinions on the percentage of CFIT avoidable thanks to EGNOS but we consider all of them



- We have gathered many opinions in the industry about the significant EGNOS contribution to CFIT avoidance
  - "… A major cause of CFIT during approach is the lack of vertical guidance. The Flight Safety Foundation has shown there is a 7-fold reduction in approach accidents when vertical guidance is provided compared to non-vertically guided (i.e., non-precision) approaches (Flight Safety Foundation Report: "Safety Benefits of the WAAS during Instrument Approaches") …"
    FAA on WAAS, WAAS benefit register
  - "… When we talk about CFIT during approaches, I think it is defendable to claim that the vertical guidance provided by SBAS or WAAS is as good as an ILS (and may be better due to the ability for moving map displays) in reducing risk of CFIT however there will still be occasions when CFIT happens due to mechanical failure or human error. I would agree that 90% reduction is a fair estimate …"
    NTSB, Safety studies and Statistical Analysis Director
  - "… Our data shows us that much of the time, even when vertical guidance is available it is not used. The most complete solution for CFIT challenge is TAWS but speaking about SBAS if we exclude human errors and mechanical failures the percentage of CFIT that could be avoided thanks to EGNOS would be around 80 or 90% …"
    FSF, Director of Technical Programs
  - "… SBAS is far exceeding the performance that we expected when we commissioned it six years ago. SBAS or WAAS in our case will have an impact on CFIT, if I have to estimate I would say that 95% of CFIT could be avoided …"
    FAA, Satellite Navigation Program Office
  - "… Implementation of continuous descent approach would provide most of the benefit of avoidance of CFITs, I would say that SBAS could eliminate 75% of them …"
    FAA, PBN Specialist
  - "… In my opinion when you are equipped with vertical guidance there is no reason for CFIT so I would say that SBAS could prevent 100% of them …"
    South African Airways, PBN Specialist
  - "… WAAS provides many safety advantage – aviation experts predict that WAAS will reduce accidents by 80% during instrument approaches …"
    Jet Pro on WAAS
- The position of Eurocontrol is contrasting the one of other experts within the industry
  - "… The EGNOS benefit will be mitigated by GPS NPA, but I don't have figures on that I would estimate 20-30% is the proper ratio, this is true at least for what concern Europe while in the USA it is different …"
    Eurocontrol, Navigation Domain Manager
  - "… The ratio used is 30% and this estimate has to be considered conservative …"
    Helios on ISA CBA for Eurocontrol

Source: L.E.K. interviews

In addition to FAA opinion stated on its website L.E.K. has collected some quotes supporting EGNOS contribution to Navaids phasing out which are contrasting the position of Eurocontrol

Pro

- We have gathered many opinions in the industry about the EGNOS contribution to traditional navaids phasing out
  - "… Significant government cost savings due to the elimination of maintenance costs associated with older, more expensive ground-based navigation aids (to include NDBs, VORs, DMEs, and most Category 1 ILSs) …"
    FAA on WAAS
  - "… Once everyone will use EGNOS the navaids phasing out could start …"
    ENAV, Director
  - "… EGNOS can contribute to navaids in terms of no need for some additional ILS and for VOR and NDB at least those used in the approach phase …"
    GIANT, Coordinator
  - "… I wouldn't divide among different categories of VOR and NDB (those used in approach or in navigation phases), all of them are almost obsolete and I confirm that their phasing out is due to EGNOS not all the GNSS system …"
    ENAV, Flight Operation Manager
  - "… In my opinion is it correct to consider EGNOS the main contributor to the navaids phasing out of VOR and NDB, I wouldn't say it is referable to GPS. EGNOS is the future, we started to produce helicopters without some old equipage because if we can have EGNOS we can a lot of savings and don't rely on these traditional navaids …"
    Agusta Westland, Senior Marketing Manager
  - "… Your analysis about Navaids phasing out seems accurate to me …"
    South African Airways, PBN Specialist

Against

- The position of Eurocontrol is contrasting the one of FAA and of other decision makers and experts within the industry
  - "… We don't agree with the FAA position stated on their website and we consider Navaids phasing out a benefit attributable to the all GNSS system …"
    Eurocontrol, Senior Expert: Navigation (CNS CoE)

Source: L.E.K. interviews

CBA ADS-B inputs

Input	Value	Source
Minutes saved thanks to ADS-B	• 2.1	ASECNA
Share of movements in AFI without radar coverage	• 68.8%	Kenya Airways
Fuel saved	• Unit cost: €/litre 0.27 • Average fuel consumption: litre/minute 24.6	IATA, Airbus, Cessna, Falcon, Bombardier

Source: L.E.K. interviews and analysis

CBA Navaids inputs

Input	Value	Source
Population	• DME: 3 • VOR: 60 • NDB: 556 • ILS: 44 • VOR/DME: 174 • ILS/DME: 62	Garmin
Backlog	• DME: 18% • VOR: 0% • NDB: 0% • ILS: 18% • VOR/DME: 18% • ILS/DME: 18%	Eurocontrol
Lifetime	• 20 years	ASECNA
% of underperforming navaids	• DME: 7.5% • VOR: 7.5% • NDB: 10.0% • ILS: 15.0% • VOR/DME: 7.5% • ILS/DME: 10.0%	Sia Solutions
Capex (€/000)	• DME: 301.0 • VOR: 601.8 • NDB: 75.0 • ILS: 578.2 • VOR/DME: 902.7 • ILS/DME: 879.1	
Opex (€/000)	• DME: 10.0 • VOR: 10.0 • NDB: 5.0 • ILS: 10.0 • VOR/DME: 20.0 • ILS/DME: 20.0	

Source: L.E.K. interviews and analysis

CBA DDC inputs

Input	Value	Source
% of DDC occurrence	• 0.19%	GIANT, Airnostrum in Spain, africaonline, hridir, Eurocontrol
EGNOS effectiveness against DDCs	• 48.5%*	Eurocontrol
Average DDC cost	• Fuel: 14.1 €/minute	Air Transport Association
	• Crew: 1.8 €/minute	
	• Maintenance: 6.9 €/minute	
	• Aircraft ownership: 5.3 €/minute	
	• Other: 1.3 €/minute	
	• Average time lost: Delay 50 minutes, Diversion 66 minutes, Cancellation 90 minutes	Eurocontrol
	• Average passenger time value: 0.01 €/minute	FAA
	• Average number of passengers involved: 43	Eurocontrol
	• Weight of DDC category: Delay 75%, Diversion 20%, Cancellation 5%	Eurocontrol

Note: * Even though Giant – Airnostrum study states 81.1% Eurocontrol has formally updated the number
Source: L.E.K. interviews and analysis

CBA Aircraft equipage inputs

Input	Value	Source
SBAS receiver	• T2=€14,000; J2=€35,000 (2 SBAS rec.)	Honeywell
Integration	• T2=€8,000; J2=€30,000	
Installation	• T2=€3,450; J2=€12,000	
Crew training	• T2=€3,000; J2=€3,000	
Documentation	• T2=€700; J2=€5,000	
Certification	• T2=€2,000; J2=€40,000	

Note: T2=Light multi-engine pressurised turboprop aircraft; J2= Midsize business jet aircraft
Source: L.E.K. interviews and analysis

CBA Procedures inputs

Input	Value	Source
Runways with EGNOS	• Number of runways: 1,101 • Number of IFR-LPV runways: 251 • Share of runways with EGNOS: 46%	Garmin, Kenya Airways
Costs	• Costs of procedures: €21,186 • Cost of surveying: €3,107	ATNS

Source: L.E.K. interviews and analysis

CBA Ground infrastructure deployment and operation inputs

Input	Value	Source
REM	• Number of REMs: 2 • Cost per REM (capex): €4,000,000 • Data processing fee per REM (opex): €2,000,000 • Maintenance (opex): 10% of capex	ASECNA and L.E.K. estimate

RIMS	• Number of RIMSs: 30
	• Capex per RIMS: €1,237,500
	  • RIMS Site surveys: €3,333
	  • RIMS equipment, deployment and qualification: €916,667
	  • RIMS VSAT comms network: €183,333
	  • Upgrade of calibration aircraft (ATR42): €8,333
	  • Safety case and training: €109,167
	  • Regulatory issues: €16,667
	• Opex per RIMS: €28,333
	  • ISA Staff: €1,667
	  • Communications: €15,000
	  • Administration and ISA service provider fee recovery (8% of ops before ESSP fee) : €11,667
	• Maintenance (opex): 10% of capex	

Source: L.E.K. interviews and analysis