GNSS/EGNOS services and applications in civil aviation

Euromed GNSS II project/MEDUSA:
Lebanon national workshop
EGNOS SoL operation in civil aviation
EGNOS SoL - main principles (1)

• Designed:
  Compliant to APV- I
  To support civil aviation operations down to LPV minima at any qualifying runway (CAT-I)
  To meet ICAO SARPs
  Compliant to RTCA Minimum Operational Performance Standards (MOPS) for airborne navigation equipment using the GPS augmented by SBAS

• Enabling Performance Based Navigation (PBN)
• Not requiring the installation (and maintenance) of ground-based landing NAVAIDs
• Requiring certified avionics in accordance with ICAO SARPs
• Interoperable with other SBAS to enable aircraft seamless transitions between SBAS systems and interoperable SBAS avionics
# EGNOS SoL - main principles (2)

<table>
<thead>
<tr>
<th>Typical Operation</th>
<th>Horizontal Accuracy (95%)</th>
<th>Vertical Accuracy (95%)</th>
<th>Integrity</th>
<th>Time-To-Alert (TTA)</th>
<th>Horizontal Alert Limit (HAL)</th>
<th>Vertical Alert Limit (VAL)</th>
<th>Continuity</th>
<th>Availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>En-route (oceanic / continental low density)</td>
<td>3.7 km (2.0 NM)</td>
<td>N/A</td>
<td>1 - 1x10^-7/h</td>
<td>5 min</td>
<td>7.4 km (4 NM)</td>
<td>N/A</td>
<td>1 - 1x10^-4/h to 1 - 1x10^-8/h</td>
<td>0.99 to 0.99999</td>
</tr>
<tr>
<td>En-route (continental)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>En-route, Terminal</td>
<td>0.74 km (0.4 NM)</td>
<td>N/A</td>
<td>1 - 1x10^-7/h</td>
<td>15 s</td>
<td>1.65 km (1 NM)</td>
<td>N/A</td>
<td>1 - 1x10^-4/h to 1 - 1x10^-8/h</td>
<td>0.99 to 0.99999</td>
</tr>
<tr>
<td>Initial approach, Intermediate approach, Non-precision</td>
<td>220 m (720 ft)</td>
<td>N/A</td>
<td>1 - 1x10^-7/h</td>
<td>10 s</td>
<td>556 m (0.3 NM)</td>
<td>N/A</td>
<td>1 - 1x10^-4/h to 1 - 1x10^-8/h</td>
<td>0.99 to 0.99999</td>
</tr>
<tr>
<td>Approximate approach with vertical guidance (APV-I)</td>
<td>16.0 m (52 ft)</td>
<td>20 m (66 ft)</td>
<td>1 - 2x10^-7</td>
<td>10 s</td>
<td>40 m (130 ft)</td>
<td>50 m (164 ft)</td>
<td>1 - 8x10^-6/15 s</td>
<td>0.99 to 0.99999</td>
</tr>
</tbody>
</table>

**ICAO operational requirements**

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Euromed GNSS II national workshop, Beirut, 26 November 2013
PBN (Performance-Based Navigation) concept

ICAO PBN Manual/Doc. 9613 specifies RNAV or RNP performance requirements for a certain operation in the context of a particular airspace concept, when supported by NAVAIDs infrastructure.

Applications:

- RNAV x
- RNP x
  With on-board performance monitoring and alerting

Application: e.g. operations, en-route, approach, take-off, landing

Infrastructure: Ground-based NAVAIDs or Space-based NAVAIDs supporting the application (e.g. VOR, DME, GNSS, avionics)

Specification: performance indicators value required for the application using the infrastructure
PBN performance indicators

Required for a navigation specification:

- **Position accuracy** - difference between a computed and a true position
- **Integrity** - measure of the trust that can be placed in the correctness of the provided information
- **Availability** - the percentage of time that the positioning and integrity are available and according to the required values (performances) under stated conditions and within the specified coverage area
- **Continuity** - the capability to provide the positioning and integrity according to the specified performances without non-scheduled interruptions during the intended operation
- **Time-to-alert** - the maximum time allowed from the onset of a failure condition up to the annunciation in the aircraft
RNP Approaches according to PBN

Chart title: RNAV (GNSS)

- **LNAV**
  - GPS NPA expected to be flown with CDFA

- **LP**
  - SBAS-based NPA
  - SBAS supported Localiser Performance

- **LNAV/VNAV**
  - APV
  - Baro-VNAV

- **LPV**
  - APV
  - SBAS
  - SBAS supported Localiser Performance with vertical guidance

Chart title: RNAV (RNP)

- **RNP AR APCH**

- **LNAV/VNAV**

**PANS-OPS Terminology** | **PBN Terminology** | **Chart Minima** | **Minimum Sensor**
---|---|---|---
NPA | RNP APCH down to | LNAV (MDA) | Basic GNSS
APV Baro-VNAV | RNP APCH down to | LNAV/VNAV (DA) | Basic GNSS + Baro-VNAV
- | RNP APCH down to | LP (MDA) | SBAS
APV SBAS | RNP APCH down to | LPV (DA) | SBAS
ICAO Assembly Resolution A37-11

Urges all States to implement RNAV and RNP air traffic services (ATS) routes and approach procedures in accordance with the ICAO PBN concept laid down in the PBN manual (ICAO PBN Manual/Doc. 9613)

PBN benefits:
• Environment-friendly
• Improving safety
• Improving operating returns
• Increasing airspace capacity
• The global rollout

ICAO states that GNSS enables PBN and provides navigation guidance for all phases of flight, from en-route to precision approach
APV as ICAO PBN strategy enabler

• **ICAO Assembly (36th Assembly Oct 2007) resolutions:**
  Implementation of APVs (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:
  –30% by 2010
  –70% by 2014

• **ICAO Assembly (37th Assembly Oct 2010) resolutions:**
  Implementation of straight-in LNAV only procedures, as an exception, for instrument runways at aerodromes where there is no local altimeter setting available and where there are no aircraft suitably equipped for APV operations

• **Enabler for the future PBN IR (mandatory) objectives achievement**
**SBAS integrity concept (1)**

**Integrity risk:** the probability that the position error is larger than the alert limit for the intended operation and the user is not warned within the time to alert (TTA)

**Alert Limit:** the error tolerance not to be exceeded without issuing an alert. There is a Horizontal and Vertical Alert Limits, HAL and VAL for each operation

**Time To Alert:** The maximum allowable time elapsed from the onset of the system being out of tolerance until the user is alerted

The Horizontal Protection Level (HPL) is the radius of a circle in the horizontal plane, centered at the true position, which describes the region which is assured to contain the indicated horizontal position.

The Vertical Protection Level (VPL) is the half length of a segment on the vertical axis with its center being at the true position, which describes the region which is assured to contain the indicated vertical position.

**SYSTEM SITUATIONS**

- **System Available** (HPL < HAL)
- **System Unavailable** (HPL > HAL)
- **Out Of Tolerance** (HPE > HPL)

HPE: Horizontal Position Error

VPE: Vertical Position Error
SBAS integrity concept (2)
SBAS in ICAO’s approaches

General Evolution of Approaches

- **NPA** (Non Precision Approaches)
  - Conventional
  - RNP APCH
  - LNAV

- **APV** (Approaches with Vertical Guidance)
  - Baro/VNAV
  - SBAS LPV

- **PA** (Precision Approaches)
  - Conventional
  - GBAS Approach

Sensors

- VOR/DME/NDB Localizer
- GPS
- GPS + Baro
- GPS + SBAS
- ILS
- GPS + GBAS
SBAS in ICAO’s RNP approaches

Chart title: RNAV (GNSS)

RNP APCH

Without Vertical guidance
- LNAV
  - GPS NPA
  - Approach expected to be flown with CDFA
- LP
  - SBAS supported Localiser Performance
- LNAV/VNAV
- APV Baro

With Vertical guidance
- LPV
  - APV SBAS
  - SBAS supported Localiser Performance with vertical guidance

Chart title: RNAV (RNP)

RNP AR APCH

With Vertical guidance
- LNAV/VNAV
Non Precision Approaches (NPA)
Use Conventional Navigation: VOR, DME to the MDH for VFR landing

Precision Approaches (PA)
Use Instrument Landing system: ILS, GBAS. Provide Lateral and Vertical guidance on stabilised continuous descent path

Approach with Vertical Guidance (APV)
Use GNSS navigation and can use SBAS (LPV) or baro-VNAV for the vertical guidance

Higher minima
CFIT risk

Lowest minima
Costly ground installation
Local coverage

Low minima
Cost effective
Balanced solution

EGNOS
EGNOS competitive space

- **GPS**: 400 – 600 ft DH
- **GPS Inertial/SBAS**: 350 – 400 ft DH
- **SBAS**: 250 – 300 ft DH
- **SBAS/GBAS**: 200 ft DH
- **GBAS**: 0 – 200 ft DH

**Approach NAVAIDs trade off**

- **LNAV/VNAV**: 1 nm
- **LPV**: 3/4 nm
- **GLS**: 1/2 nm
- **NPA**: 3º
- **CAT I-III**: 2 nm
### Alert Limits

<table>
<thead>
<tr>
<th>Operation</th>
<th>Horizontal Alert Limit</th>
<th>Vertical Alert Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>APV-I</td>
<td>40m (130ft)</td>
<td>50m (164ft)</td>
</tr>
<tr>
<td>APV-II</td>
<td>40m (130ft)</td>
<td>20m (66ft)</td>
</tr>
<tr>
<td>CAT I</td>
<td>40m (130ft)</td>
<td>15m to 10m (50ft to 33ft)</td>
</tr>
</tbody>
</table>

#### Accuracy

<table>
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<tr>
<th>Type of Operation</th>
<th>Horizontal Accuracy</th>
<th>Vertical Accuracy</th>
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<tr>
<td>APV-I</td>
<td>16.0m (52ft)</td>
<td>20m (66ft)</td>
</tr>
<tr>
<td>APV-II</td>
<td>16.0m (52ft)</td>
<td>8.0m (26ft)</td>
</tr>
<tr>
<td>Cat-I</td>
<td>16.0m (52ft)</td>
<td>6.0m to 4.0m (20ft to 13ft)</td>
</tr>
</tbody>
</table>

**ILS-CAT I minima ~ 200 ft**  
**APV-I (LPV) minima ~250 ft**
LPV is ILS look-alike

Crew reports Flying LPV is similar and even more stable than ILS

LPV Approach Real Flight Trial
EGNOS benefits for civil aviation
EGNOS added value for civil aviation

- **Back-up** for conventional NAVAIDs
- **Instrument approach capability** for those airdromes or runways where ILS cost is not justified, with a huge increase in safety
- **Instrument navigation** in those regions not covered by conventional ground NAVAIDs
- Enabler of **procedures with curved segments** in air space scenarios with particularly difficult constraints, facilitating solutions needed in the case of:
  - Difficult orographic conditions in the terminal area
  - Environmental impact/protected zones (e.g. noise footprint impact minimisation over urban areas, natural areas/parks protection)
  - Military or security air space restricted areas
  - Border areas between countries
- Enabler of **optimised procedures** for special applications, e.g. general and business aviation, helicopters serving oil rigs
EGNOS costs vs benefits for the civil aviation community

**Benefits**

- Increased **efficiency** through the reduction in the number of **Delays, Diversions and Cancellations (DDCs)**
- Increased **safety** through the reduction of **Controlled Flight Into Terrain (CFIT)**
- Phasing out of conventional NAVAIDs

**Costs**

- Avionics
- Flight procedures
EGNOS social benefits

**Safety improvement**: EGNOS enables APV approaches, providing significant safety improvements at airports where approaches with vertical guidance are currently not available (Non Precision Approaches NPA)

**CFIT reduction of 75%** (source: Eurocontrol)

**Environmental impact reduction**:
- Noise reduction in urban areas
- CO2 emissions reductions due to optimised routes and CDA (continuous descent approach)
EGNOS economical benefits

- **DDCs reduction**: lower minima makes landing possible with lower visibility levels at airports not equipped with ILS (48% reduction ANSP/airlines estimate)
- **Time and fuel savings**: more flexible curved/segmented and continuous descent approach procedures result in time/fuel savings
- **Increased runway capacity**: EGNOS has no critical/sensitive areas, reducing the time between consecutive approach/departure aircraft operations. Approach terrain constraints are also easier to overcome. ILS backup in case of failure
- **Ground infrastructure cost savings**: decommissioning of ground based NAVAIDs, with expensive maintenance costs. Regional coverage enables operations in areas with insufficient conventional NAVAIDs infrastructure
- **Enhanced efficiency in air space use**: supporting en-route and terminal area PBN procedures, allows more aircraft to follow preferred trajectories
- **Reduced costs for procedure compared to ILS** (on other conventional NAVAIDs), since periodic flight verifications are not required
- **Reduced aircrew training costs** when all approaches can be flown using vertical guidance
EGNOS retrofitting for aircraft in service (1)

- SBAS receiver
- Integration
- Installation
- Documentation
- Certification
- Other cost

Number of aircraft
Crew training
EGNOS retrofitting for aircraft in service (2)

EU certification process

- Service Bulletin available
  - no
  - yes
  - Minor change?
    - no
      - Aircraft in Service Process
    - yes
      - Contact a DOA approved by EASA Part 21
      - Technical report for the installation
      - DOA acceptance
      - EASA application Form 32 + Technical Report for the installation
      - EASA acceptance

- STC available
  - no
  - yes
    - STC release
      - Technical report for the installation
      - EASA application Form 33 (*)
      - EASA acceptance

- Installation and Certification approval
  - Installation of the receiver
    - Installation manual - SB / STC
    - REMARKS: The installation has to be performed by a Maintenance centre approved by EASA Part 146
  - Certificate to Release to Service (CRS)
  - (*) The application should be done by a DOA approved by EASA Part 21
EGNOS scenario in Europe for civil aviation
EGNOS SoL - Service Definition Document (SDD) (1)

- EGNOS SoL SDD describes the characteristics and conditions of access to the service. Published on June 2013 (http://www.essp-sas.eu/service_definition_documents)

- EGNOS Service Notices generated whenever there is any complementary information to be provided to users that could affect the SoL SDD contents (http://www.essp-sas.eu/service_notices)
Establishes the European Framework for EGNOS SoL Service implementation in civil aviation

Regulated framework under Supervisory Authority oversight required for a Safety of Life application (ref. EU Civil Aviation application Single European Sky - SES):

- ESSP SAS certified as ANSP
- EGNOS System verified (Interoperability regulation)
- Need for EGNOS Working Agreements

Freely offered for all phases of flight to:

- Airspace Users (as defined by SES regulation) equipped with EGNOS certified receivers (TSOS/ETSOs C144, C145 or C146)
- Certified Air Navigation Service Providers (ANSPs) having signed an EGNOS Working Agreement (EWA) with ESSP
EGNOS institutional and service provision frame

European Commission (customer) → Contract → EGNOS Service Provider [AENA, DGAC, ENAV, NATS, NAV, Skyguide, DFS] → EWA

Certification → EASA

ANSPs → Service → ANSPs

Procedures → Aeronautical users

Design Authority

Euromed GNSS II national workshop, Beirut, 26 November 2013
In Europe, EGNOS is subject to regulation/approval by “EASA system” (including NSAs)
The need for a EWA

EUROPEAN SES regulatory framework analysis

RE (CE) 550/2004, Article 10: "Air navigation service providers shall formalise their working relationships by means of written agreements or equivalent legal arrangements, setting out the specific duties and functions assumed by each provider and allowing for the exchange of operational data between all service providers in so far as general air traffic is concerned. Those arrangements shall be notified to the national supervisory authority or authorities concerned."

RE (CE) 2096/2005 Annex I, 7. "An air navigation service provider which avails itself of services of another air navigation service provider shall ensure that the agreements cover the allocation of liability between them."
WHO
Between the ANSP and the EGNOS Service Provider

WHY
To define roles and responsibilities for the actors involved
To formalize the working procedures and interface

WHAT (contents)
Contractual document (including liability)
Contingency coordination
NOTAM proposal
Data recording
Collaborative decision making
Service commitment with reference to EGNOS SoL SDD Doc
Identification of the main focal points
Service arrangements

WHEN
As soon the procedures implementation process is defined and decided
MEDUSA assistance action in relation to EWA

For interested non-EU countries/Outcomes of the technical workshop @ ESSP October 2013

- Institutional + regulatory action to be undertaken prior the negotiation and the signature of EWA with ESSP
- Institutional action - bilateral discussion/dialogue between the State and Europe
- Regulatory action - agreement concerning civil aviation safety harmonisation/regulatory equivalence between the State and Single European Sky relevant regulations
- No EWA negotiation with ESSP until the appropriate framework is defined. The EWA will reflect the agreed framework

MEDUSA assistance action:

- Elaboration of a compliance matrix towards relevant requirements extracted from current applicable SES regulations
- Case study: Tunisia (MASC ?)
EGNOS in Europe: facts and figures
Status of EGNOS introduction in Europe (1)

LPV Implementation Plan for 2014

Source: ESSP (October 2013)

APV-Baro procedures where EGNOS has been authorized for vertical guidance
OVER 200 NEW EGNOS BASED PROCEDURES IN MORE THAN 100 AIRPORTS EXPECTED BEFORE END OF 2014

15 NEW EUROPEAN COUNTRIES EXPECTED TO PUBLISH THEIR FIRST EGNOS BASED APPROACH PROCEDURE BEFORE END OF 2014

Source: ESSP (October 2013)
Examples of real case applications/scenarios of EGNOS use

- Scenario at Valencia (Spain)
- Scenario at Saarbrücken (Germany)
- Scenario at Pamplona (Spain)
- Scenario at Egelsbach (Germany)
- EGNOS pioneer operators
- EGNOS pioneer airports
Valencia (Spain)

Aircraft model/operator: CRJ-1000NG/Air Nostrum (RC-GPS 4000S)
Scenario characteristics: urban noise restrictions
Expected date: Q1 2014
Demonstration objectives:
• Curved departure for RWY 12
• Curved approach (RF leg) prior (2 nm) to FAP
• and final transition to LPV RWY30

Euromed GNSS II national workshop, Beirut, 26 November 2013
Aircraft model/operator: Cessna 340 /Navart (Garmin G1000)

Scenario characteristics: noise restrictions, terrain and airspace limitations (France border & ATC coordination)

Expected date: Q1 2014

Demonstration objectives:
• Assessment and introduction of RF legs prior to FAF with transition to LPV
• RNP AR avionics requirement analysis with minima equivalent to LPV
Pamplona (Spain)

Aircraft model/operator: CRJ-1000NG/Air Nostrum (RC-GPS 4000S)
Scenario characteristics: very difficult terrain environment
Expected date: Q1 2014

Demonstration objectives:
- Reduction of approach minima (LPV to non ILS RWY 33)
- More stabilised final segment approach
- Reduction of departure climb gradient at RWY15
Egelsbach (Germany)

Aircraft model/operator: Hawker 750/NetJets (RC-GPS 4000S)
Scenario characteristics: airspace restrictions
Expected date: Q1 2014
Demonstration objectives:
• IFR procedures with lower minima
• Advanced RNP with transition to LPV (RWY 27)
• RF in the Missed Approach MAP final segment
• Avoid ATC conflicts & decongest Frankfurt TMA area
EGNOS pioneer operators

4 main avionics manufactures:
- Thales
- Rockwell Collins
- Universal
- Garmin

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Operators benefitting from EGNOS

- **REGIONAL**
  - Aurigny
  - Air Nostrum
  - Loganair
  - CityJet (VLM)
  - Hebridean Air
  - Skybus
  - Danish Air Transport

- **BUSINESS**
  - Inaer
  - NetJets
  - specsavers
  - Bell 412
  - Hawker 750
  - Piper 390

- **GENERAL**
  - NLR
  - Air Charters Europe
  - Aviation South West
  - Royal Star-Aero
  - Dutch & Martin Air Flight Academies

Source: GSA/EC
Thank you!
Questions?

MEDUSA