GNSS/EGNOS services and applications in civil aviation

Euromed GNSS II project/MEDUSA:
Algeria national workshop
Index

EGNOS (European Geostationary Navigation Overlay Service)

EGNOS scenario in Europe for civil aviation

EGNOS benefits for civil aviation

EGNOS in Europe: facts and figures

MEDUSA EGNOS Safety of Life service demonstration for civil aviation

MEDUSA planned action for Algeria/civil aviation
EGNOS main principles

EGNOS is a Satellite Based Augmentation System (SBAS)

1. GPS Constellation
2. Ranging and Integrity Monitoring Stations (RIMS)
3. Mission Control Centres (MCC)
4. Navigation Land Earth Stations (NLES)
5. 3 geostationary EGNOS Satellites

... relay error corrections to users
... uplink error corrections to EGNOS satellites...
... receive GPS data and send it to MCC...
... process GPS data to determine errors...
... GPS position accuracy
... EGNOS position accuracy
EGNOS main principles (2)

- Differential Corrections
- Estimate of residual positioning error
- Use / Don’t use message + Time to Alert

- + Accuracy
- + Continuity + Availability
- + Integrity + Safety

Euromed GNSS II national workshop, Alger, 13 June 2013
EGNOS main principles (3)

A SBAS is a navigation system that supplements/augments GNSS providing
- A more accurate navigation service than GNSS
- The high level of integrity required for most aviation navigation operations, and thus a more reliable navigation service than GNSS alone

SBAS enables Localizer Performance with Vertical guidance (LPV) approaches:
- LPVs are operationally similar to a CAT-I ILS, but are more economical
- LPVs do not require the installation or maintenance of navigation aids at the airport since the navigation service is provided to the aircraft entirely by satellites

SBAS technology provides the opportunity to cover very large areas of airspace and areas formerly un-served by navigation aids

SBAS also adds increased capability, flexibility, and in many cases, more cost-effective navigation options than legacy ground-based navigation aids

SBAS broadcast the augmentation information in the same frequency and with the same message format as GPS, facilitating avionics design, integration and certification, compared to other augmentations systems
## EGNOS services and coverage

<table>
<thead>
<tr>
<th>Services</th>
<th>Open</th>
<th>EGNOS OS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Free to air; mass market; better than GPS</td>
<td>EGNOS EDAS</td>
</tr>
<tr>
<td>Commercial</td>
<td>High accuracy; professional market</td>
<td>EGNOS SoL</td>
</tr>
<tr>
<td>Safety of Life</td>
<td>Integrity and authentication of the signal</td>
<td></td>
</tr>
</tbody>
</table>

![Map of EGNOS coverage](image)
EGNOS today’s performances vs coverage

Today EGNOS service coverage

EGNOS SoL (APV-I) availability on 28 May 2013

Source: ESSP
In the future operators will be able to travel around the world supported by SBAS

There are plans to extend WAAS coverage over South America, and also some national initiatives
EGNOS SoL main principles

- Designed:
  Compliant to APV- I
  To support civil aviation operations down to LPV (Localiser Performance with Vertical guidance) minima at any qualifying runway (CAT-I)
  In accordance to the ICAO SARPs criteria
  To be 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
SBAS (EGNOS) interoperable avionics

<table>
<thead>
<tr>
<th>Operational Class</th>
<th>Phases of Flight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1</td>
<td>Oceanic and domestic en route, terminal, approach (LNAV), and departure operation</td>
</tr>
<tr>
<td>Class 2</td>
<td>Oceanic and domestic en route, terminal, approach (LNAV, LNAV/NAV), and departure operation</td>
</tr>
<tr>
<td>Class 3</td>
<td>Oceanic and domestic en route, terminal, approach (LNAV, LNAV/NAV, LP, LPV), and departure operation</td>
</tr>
<tr>
<td>Class 4</td>
<td>Equipment that supports only the final approach segment operation</td>
</tr>
</tbody>
</table>

Each SBAS system has been developed to meet ICAO SARPs Annex 10 standards.

The Interoperability Working Group (IWG) meets regularly to maintain interoperability as systems evolve.

SBAS avionics are intended as interoperable and developed in accordance with ICAO SARPs to enable aircraft seamless transitions between SBAS systems.
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
ICAO navigation specifications

Navigation Specifications

RNP specifications
(includes a requirement for on-board performance monitoring and alerting)

Designation
RNP 4
RNP 2
Oceanic and remote navigation applications

Designation
RNP 2
RNP 1
A-RNP
RNP AR APCH
RNP 0.3
En-route and terminal applications

Designation
RNP with additional requirements to be determined (e.g. 3D, 4D)

RNAV specifications
(no requirement for on-board performance monitoring and alerting)

Designation
RNAV 10
Oceanic and remote navigation applications

Designation
RNAV 5
RNAV 2
RNAV 1
En-route and terminal navigation applications

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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
RNP Approaches according to PBN

**Chart title: RNAV (GNSS)**

- Without Vertical guidance
  - LNAV
  - LP
  - GPS NPA expected to be flown with CDFA
  - SBAS-based NPA
  - SBAS supported Localiser Performance

- With Vertical guidance
  - LNAV/VNAV
  - APV
  - Baro-VNAV

**Chart title: RNAV (RNP)**

- Without Vertical guidance
  - LNAV/VNAV
  - APV
  - SBAS supported Localiser Performance

- With Vertical guidance
  - LNAV/VNAV
  - APV
  - SBAS supported Localiser Performance with vertical guidance

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<table>
<thead>
<tr>
<th>PANS-OPS Terminology</th>
<th>PBN Terminology</th>
<th>Chart Minima</th>
<th>Minimum Sensor</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPA</td>
<td>RNP APCH down to</td>
<td>LNAV (MDA)</td>
<td>Basic GNSS</td>
</tr>
<tr>
<td>APV Baro-VNAV</td>
<td>RNP APCH down to</td>
<td>LNAV/VNAV (DA)</td>
<td>Basic GNSS + Baro-VNAV</td>
</tr>
<tr>
<td>-</td>
<td>RNP APCH down to</td>
<td>LP (MDA)</td>
<td>SBAS</td>
</tr>
<tr>
<td>APV SBAS</td>
<td>RNP APCH down to</td>
<td>LPV (DA)</td>
<td>SBAS</td>
</tr>
</tbody>
</table>

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GPS NPA expected to be flown with CDFA
SBAS-based NPA
SBAS supported Localiser Performance

PANS-OPS Terminology
PBN Terminology
Chart Minima
Minimum Sensor
## ICAO PBN Roadmap

### PBN

<table>
<thead>
<tr>
<th>PBN</th>
<th>Block 0</th>
<th>2018</th>
<th>Block 1</th>
<th>2023</th>
<th>Block 2</th>
<th>2028</th>
<th>Block 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>En-Route Oceanic and Remote Continental</strong></td>
<td>RNAV 10 (RNP 10)</td>
<td>RNAV 5</td>
<td>RNAV 2</td>
<td>RNP 2</td>
<td>Advanced RNP</td>
<td>RNP 0.3 (Helicopter only)</td>
<td></td>
</tr>
<tr>
<td><strong>En-Route Continental</strong></td>
<td>RNAV 10 (RNP 10)</td>
<td>RNAV 5</td>
<td>RNAV 2</td>
<td>RNP 2</td>
<td>Advanced RNP</td>
<td>RNP 0.3 (Helicopter only)</td>
<td></td>
</tr>
<tr>
<td><strong>Terminal Airspace: Arrival and Departure</strong></td>
<td>RNAV 1</td>
<td>RNAV 1</td>
<td>Basic RNP 1</td>
<td>RNP 0.3 (Helicopter only)</td>
<td>Advanced RNP</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Approach</strong></td>
<td>RNP APCH (SBAS: LPV, BARO VNAV: LNAV/VNAV, Basic GNSS: LNAV)</td>
<td>RNP APCH (where beneficial)</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

*Migration path based on Region/States requirements*

*Source: ICAO twelfth Air Navigation Conference Montréal, 19 to 30 November 2012 (AN-Conf/12-IP/3 28/8/12)*
### ICAO Navigation roadmap

<table>
<thead>
<tr>
<th>Enablers</th>
<th>2018</th>
<th>2023</th>
<th>2028</th>
<th>Block 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Conventional</strong></td>
<td></td>
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<tr>
<td>ILS/MLS</td>
<td></td>
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<tr>
<td>Retain to support precision approach and to mitigate GNSS outage</td>
<td></td>
<td></td>
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<tr>
<td>DME</td>
<td></td>
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<tr>
<td>Optimize existing network to support PBN operations</td>
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<tr>
<td>VOR/NDB</td>
<td></td>
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</tr>
<tr>
<td>Rationalize based on need and equipage</td>
<td></td>
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<tr>
<td><strong>Satellite-based</strong></td>
<td></td>
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<tr>
<td>Core GNSS Constellations</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Single-frequency (GPS/GLONASS)</td>
<td></td>
<td>Multi-Freq/Multi-Constellation (GPS/GLONASS/Bepdou/Galileo)</td>
<td></td>
<td></td>
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<tr>
<td>GNSS Augmentations</td>
<td></td>
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<tr>
<td>SBAS, GBAS Cat I</td>
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<tr>
<td>GBAS Cat II/III</td>
<td></td>
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<tr>
<td>Multi-Freq GBAS/SBAS</td>
<td></td>
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</tr>
<tr>
<td><strong>Capability</strong></td>
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<tr>
<td><strong>PBN</strong></td>
<td></td>
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<tr>
<td>(see PBN Roadmap)</td>
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</tr>
<tr>
<td>PBN Operations</td>
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<td></td>
</tr>
<tr>
<td>B0-65, B0-05, B0-10</td>
<td>B1-10, B1-40</td>
<td>B2-05</td>
<td>B3-05, B3-10</td>
<td></td>
</tr>
<tr>
<td><strong>Precision Approach</strong></td>
<td></td>
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<tr>
<td>ILS/MLS, GBAS Cat I</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Cat I/II/III Landing</td>
<td></td>
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<tr>
<td>GBAS Cat II/III</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Cat I/II/III, SBAS LPV 200</td>
<td>B0-65</td>
<td>B1-65</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: ICAO twelfth Air Navigation Conference Montréal, 19 to 30 November 2012 (AN-Conf/12-IP/3 28/8/12)
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
### GNSS elements

The GNSS is a recognized standard aid to air navigation  

GNSS services shall be provided using various combinations of the following elements:

<table>
<thead>
<tr>
<th>Basis Constellations</th>
<th>Global Positioning System - GPS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Global Navigations Satellite System - GLONASS</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Augmentation Systems</th>
<th>Aircraft-Based Augmentation System - ABAS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Satellite Based Augmentations System - SBAS</td>
</tr>
<tr>
<td></td>
<td>Ground-Based Augmentation System - GBAS</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Airborne GNSS Receiver</th>
<th>Receivers</th>
</tr>
</thead>
</table>
## ICAO operational requirements

<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) (Note 6)</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>3.7 km (2 NM)</td>
<td></td>
<td>N/A</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 approach (NPA), Departure</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>Approach operations with vertical guidance (APV-I)</td>
<td>16.0 m (52 ft)</td>
<td>20 m (66 ft)</td>
<td>1 - 2x10^-7 in any approach</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>

**GPS stand alone is not compliant with ICAO performance requirements**

**EGNOS SoL allows to fulfil the requirements**
**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)

- **H Alarm Limit**
- **H Protection Level (HPL)**
- **Computed position**
- **True position**

**Legend:**
- **VAL**
- **VPL**
- **flight phase ok**
- **flight phase not ok**
- **horizontal protection level HPL**
- **horizontal alert limit HAL**

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SBAS in ICAO’s approaches
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
    - With Vertical guidance
      - LP
        - SBAS supported Localiser Performance
      - LNAV/VNAV
      - APV Baro
      - LPV
        - APV SBAS
        - SBAS supported Localiser Performance with vertical guidance

- **Chart title: RNAV (RNP)**
  - **RNP AR APCH**
    - With Vertical guidance
      - LNAV/VNAV
**APCH NAVAIDs trade off**

**Non Precision Approaches (NPA)**
Use Conventional Navigation: VOR, DME to the MDH for VFR landing

- Higher minima
- CFIT risk

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

- Lowest minima
- Costly ground installation
- Local coverage

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

- Low minima
- Cost effective
- Balanced solution

*EGNOS*
APCH GNSS NAVAIDs trade off

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
- LNAV/VNAV
- LPV
- GLS
- CAT I-III

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EGNOS APV/CAT-I APCH benchmarking

### 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>
<thead>
<tr>
<th>Type of Operation</th>
<th>Horizontal Accuracy</th>
<th>Vertical Accuracy</th>
</tr>
</thead>
<tbody>
<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>

### Procedure Minima

ILS-CAT I minima ~ 200 ft  
APV-I (LPV) minima ~250 ft

APV-I is ILS look-alike
LPV is ILS look-alike

Crew reports Flying LPV is similar and even more stable than ILS.
EGNOS scenario in Europe for civil aviation
EGNOS institutional and service provision frame

1. **Design Authority**: ESA
2. **Contract**: EGNOS Service Provider [AENA, DGAC, ENAV, NATS, NAV, Skyguide, DFS]
3. **Service**: ANSPs
4. **Certification**: EASA
5. **EWA**: Service
6. **Procedures**: Aeronautical users
7. **Customer**: European Commission

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In Europe, EGNOS is subject to regulation/approval by “EASA system” (including NSAs)
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
EGNOS retrofitting for aircraft in service (1)

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

- Number of aircraft
- Crew training

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EGNOS retrofitting for aircraft in service (2)

EU certification process

- Aircraft in Service Process
  - Service Bulletin available
    - no
    - STC available
      - no
      - Minor change?
        - no
        - yes
          - yes
          - Technical report for the installation
            - DOA acceptance
              - EASA acceptance
                - EASA application Form 32 + Technical Report for the installation
                  - Contact a DOA approved by EASA Part 21
                    - Minor change
                      - yes
                        - Installation and Certification approval
                          - Installation of the receiver
                            - Certificate to Release to Service (CRS)
                              - REMARKS:
                                - Installation manual - SB / STC
                                - The installation has to be performed by a Maintenance centre approved by EASA Part 146
                                  - (*) The application should be done by a DOA approved by EASA Part 21
                                    - EASA application Form 33 (*)
                                      - EASA acceptance
                                        - STC release
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
**LPV vs. NPA approaches**

**Average decision height**
- NPA: 450 ft
- LPV: 250 ft

**Benefits of LPV**
- Reduction in DDC of 48%\(^1\)
- Reduction of CFIT of 75%\(^2\)
- Reduction in Ground infrastructure cost

**Cost of implementing EGNOS LPV**
- Cost of a procedure = 1 year ILS maintenance
- Cost of the receiver (if needed)

1. Eurocontrol estimate; 2. ANSP/ Airlines estimate
EGNOS in Europe: facts and figures
### Status of the EGNOS implementation in aviation

EGNOS LPV procedures already published in Europe

<table>
<thead>
<tr>
<th>Country</th>
<th>Airports</th>
<th>LPV Procedures</th>
<th>APV Baro Procedures¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>France</td>
<td>29</td>
<td>35</td>
<td>0</td>
</tr>
<tr>
<td>Switzerland</td>
<td>3</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Italy</td>
<td>3</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Guernsey</td>
<td>1</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Germany</td>
<td>39</td>
<td>11</td>
<td>71</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>75</strong></td>
<td><strong>58</strong></td>
<td><strong>71</strong></td>
</tr>
</tbody>
</table>

¹ Enabled to be flown with EGNOS vertical guidance

Source: ESSP (May 2013)
Status of EGNOS introduction in Europe (2)

Status of EWAs between ESSP and national ANSPs

Source: ESSP (May 2013)

Euromed GNSS II national workshop, Alger, 13 June 2013
Examples of operational scenarios of EGNOS use

- Scenario at Perugia (Italy)
- Scenario at Valencia (Spain)
- Scenario at Saarbrücken (Germany)
- Scenario at Pamplona (Spain)
- Scenario at Egelsbach (Germany)
- EGNOS pioneer operators
- EGNOS pioneer airports
Operational scenario at Perugia (Italy)

**Aircraft:** CESSNA CITATION VI  
**Scenario characteristics:** airspace constraints; mountainous terrain  
**Date:** November 2009  
**Demonstration objectives**  
- Procedural surveillance  
- IFR RWY 19 desirable (in case of south wind)
Operational scenario at Valencia (Spain)

Aircraft model/operator: CRJ-1000NG/Air Nostrum
Scenario characteristics: noise restrictions
Expected date: Q4 2013
Demonstration objectives:
– Curved departure for RWY 12
– Curved approach (RF leg) prior to FAP
– and final transition to LPV RWY30
Operational scenario at Saarbrücken (Germany)

Aircraft model/operator: Boeing 737/Air Berlin

Scenario characteristics: noise restrictions, terrain and airspace limitations (border)

Expected date: Q4 2013

Demonstration objectives:
– Assessment and introduction of RF legs prior to FAF with transition to LPV
– Assessment and comparison with RNP AR with minima equivalent to LPV
Operational scenario at Pamplona (Spain)

Aircraft model/operator: CRJ-1000NG/Air Nostrum
Scenario characteristics: difficult terrain environment
Expected date: Q4 2013
Demonstration objectives:
– Reduction of approach minima (LPV to non ILS RWY 33)
– More stabilised final segment approach
– Reduction of departure climb gradient at RWY15
Operational scenario at Egelsbach (Germany)

**Aircraft model/operator:** Hawker 750/NetJets

**Scenario characteristics:** airspace restrictions

**Expected date:** Q4 2013

**Demonstration objectives:**
- IFR procedures with lower minima
- Advanced RNP with transition to LPV (RWY 27)
- RF prior to FAF transition to RNP APCH
- Decongest Frankfurt area
# EGNOS pioneer operators

<table>
<thead>
<tr>
<th>Commercial</th>
<th>Commercial &amp; Medical</th>
<th>Training</th>
<th>Business &amp; Instrumentation</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="ATR 72-600" /> T</td>
<td><img src="image2" alt="Twin Otter" /> G</td>
<td><img src="image3" alt="Beechcraft 76" /> G</td>
<td><img src="image4" alt="Hawker 750" /> RC</td>
</tr>
<tr>
<td>+5x</td>
<td>2x</td>
<td>4x</td>
<td>5x</td>
</tr>
<tr>
<td><img src="image5" alt="Fokker-50" /> U</td>
<td><img src="image6" alt="BN2B Islander" /> G</td>
<td><img src="image7" alt="Piper P28A" /> G</td>
<td><img src="image8" alt="Cessna Citation II" /> G</td>
</tr>
<tr>
<td>8x</td>
<td>2x</td>
<td>4x</td>
<td>5x</td>
</tr>
<tr>
<td><img src="image9" alt="Hebridis" /> G</td>
<td><img src="image10" alt="Bell 412" /> G</td>
<td><img src="image11" alt="Diamond DA42" /> G</td>
<td><img src="image12" alt="King Air 1900D" /> G</td>
</tr>
<tr>
<td>+15x</td>
<td>2x</td>
<td>4x</td>
<td>5x</td>
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<tr>
<td><img src="image13" alt="CRJ-1000" /> RC</td>
<td><img src="image14" alt="Bell 412" /> G</td>
<td><img src="image15" alt="Diamond DA42" /> G</td>
<td><img src="image16" alt="Fairchild Metro II" /> G</td>
</tr>
<tr>
<td>+28</td>
<td>5</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

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

Euromed GNSS II national workshop, Alger, 13 June 2013
EGNOS pioneer airports

Total of 74 RWYs
Incl. 5 heliports

Publication year:
- 2011
- 2012
- 2013

Existing procedures:
- ILS (Belfast Int.)
- APV Baro (Brno)
- LNAV (Exeter)
- VOR/DME/LOC
- VFR (Barra)

Existing services:
- Full ATC (Lisbon)
- AFIS (Islay, Tiree)
- NO ATC (La Perdiz)

Euromed GNSS II national workshop, Alger, 13 June 2013
MEDUSA
EGNOS Safety of Life service
demonstration
for civil aviation
## Demonstration overview (1)

<table>
<thead>
<tr>
<th>Market/Application</th>
<th>Civil Aviation/ LPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>EGNOS Service</td>
<td>EGNOS SoL</td>
</tr>
<tr>
<td>Euromed team partners</td>
<td>MEDUSA team: INECO, ENAV, OACA, HELIOS</td>
</tr>
<tr>
<td>MEDA country</td>
<td>Tunisia</td>
</tr>
</tbody>
</table>

### Tasks
- Procedure design
- Safety assessment
- Flight demos
- Business case development
- Analysis of certification and standardization
- Exploitation towards operational use
- Promotion material, training and training material

### Outcomes
- LPV procedures, Safety assessment and business case. Training. Contribution to promotional material/“Information package on EGNOS”/contents of training material and contents for workshops. Definition of necessary steps and enablers allowing Tunisia to publish procedures in the AIP according to the AIRAC cycle.

- **Objective:** demonstration of EGNOS SoL service for LPV
- **Outcomes:** flight validation of experimental procedures and list of “to-dos” for the relevant publication
Demonstration overview (2)

- Monastir (Tunisia) airport
- RWY 07 and RWY 25
- Piaggio P180 Avanti

Team:

- Ofice de l'Aviation Civile et des Aéroports
- ENAV
- ineco
- HELIOS
- Telespazio

Euromed GNSS II national workshop, Alger, 13 June 2013
Main activities

– LPV design for RWY 07 (currently ILS)

– LPV design for RWY 25 (currently NPA)

– FAS data blocks codification

– Airborne data bases generation

– 2 validation flight trials for RWY 07

– 2 validation flight trials for RWY 25

– Business Case development

– Safety Assessment

– Exploitation towards operational use, including the analysis of certification and standardisation (AIS & AIP requirements)
Main outcomes

Real demonstration of EGNOS SoL service in civil aviation:
- Technical feasibility
- Operational feasibility
- Added value verification
- Benefits validation

Technology transfer:
- “to-do-list” + a sequence of steps for future LPV procedures operational adoption
- Training and training material
- Promotional material + Information package
Present status

RWY 25 LPV final design

OCA/H proposal for LPV to RWY 25 (ft)

<table>
<thead>
<tr>
<th>Category of Aircraft</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>LPV – 2.5%</td>
<td>275</td>
<td>287</td>
<td>295</td>
<td>305</td>
</tr>
</tbody>
</table>

Currently 460 ft

RWY 07 LPV final design

OCA/H proposal for LPV to RWY 07 (ft)

<table>
<thead>
<tr>
<th>Category of Aircraft</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>LPV – 2.5%</td>
<td>240</td>
<td>252</td>
<td>260</td>
<td>271</td>
</tr>
</tbody>
</table>

Currently 320 ft
Key dates

– **May 2013**: LPV procedures (RWY 07 & RWY 25) charts readiness

– **June 2013**: FAS data blocks codification & airborne data bases generation

– **September 2013**: Business case readiness

– **October 2013**: Training

– **October 2013**: Safety assessment readiness

– **December 2013**: Flight trials execution

– **Beginning 2014**: Exploitation towards operational use

– **May 2014**: Final workshop open to the civil aviation community of all Euromed countries
MEDUSA planned action for Algeria/civil aviation (1)

1. Specific technical assistance/support actions: a technical workshop focused on EGNOS introduction in civil aviation
2. Participation to the final workshop in Tunis focused on EGNOS SoL for civil aviation

Any further needs for specific technical assistance?

Further actions can be identified on the basis of the country’s interests and needs
MEDUSA planned action for Algeria/civil aviation (2)

**Planned technical workshop focused on EGNOS introduction in civil aviation**

**Date:** 10 October 2013  
**Place:** Madrid (Spain) @ ESSP (European Satellite Services Provider)

**Objective:** providing information on the necessary steps to be implemented for the operational adoption of EGNOS in civil aviation operations, to support the first EGNOS based operations and setting up a good basis for the corresponding feasibility assessment/decision making process

**Topics:** EGNOS SoL service performances over each country and specifically at the target locations/airports (decided by the countries), information available regarding the EGNOS SoL service roadmap (2013-2015), LPV procedures publication, EGNOS Working Agreement, examples of concrete experiences, lessons learnt and practical information

**Participating Euromed countries:** Algeria, Morocco and Tunisia (2 persons per country)

**Names/entity/contact details of the persons appointed to attend the technical workshop for Algeria to be mandatorily provided by 28th of June**
Thank you!
Questions?
## ICAO performance requirements

<table>
<thead>
<tr>
<th></th>
<th>Accuracy</th>
<th>Integrity</th>
<th>Time to Alert</th>
<th>Availability</th>
<th>Continuity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lateral 95%</td>
<td>Vertical 95%</td>
<td>Alert Limit Lateral</td>
<td>Alert Limit Vertical</td>
<td>Integrity [1]</td>
</tr>
<tr>
<td><strong>En route</strong></td>
<td>2.0 NM / 3704 m</td>
<td>N/A</td>
<td>4 NM / 7.4 km</td>
<td>N/A</td>
<td>1-10^{-7}/h</td>
</tr>
<tr>
<td><strong>En route, Continental</strong></td>
<td>0.4 NM / 740 m</td>
<td>N/A</td>
<td>2 NM / 3.7 km</td>
<td>N/A</td>
<td>1-10^{-7}/h</td>
</tr>
<tr>
<td><strong>Terminal Area</strong></td>
<td>0.4 NM / 740 m</td>
<td>N/A</td>
<td>1 NM / 1.85 km</td>
<td>N/A</td>
<td>1-10^{-7}/h</td>
</tr>
<tr>
<td><strong>Initial Approach, Departure</strong></td>
<td>220 m</td>
<td>N/A</td>
<td>0.3 NM / 0.6 km</td>
<td>N/A</td>
<td>1-10^{-7}/h</td>
</tr>
<tr>
<td><strong>Non Precision Approach</strong></td>
<td>220 m</td>
<td>N/A</td>
<td>1 NM / 1.85 km</td>
<td>NA</td>
<td>1-10^{-7}/h</td>
</tr>
</tbody>
</table>

**Approach Vertical Guidance APV I**

|                    | 16 m | 20 m | 40 m | 50 m [2] | 2-10^{-7} per approach [3] | 10 s | 0.99 to 0.99999 | 1-8\times10^{-6} in any 15 s |

**Approach Vertical Guidance APV II**

|                    | 16 m | 8 m | 40 m | 20 m | 2-10^{-7} per approach [3] | 6 s | 0.99 to 0.99999 | 1-8\times10^{-6} in any 15 s |

**Precision Approach CAT I**

|                    | 16 m | 6 m to 4 m | 40 m | 12-10 m | 2-10^{-7} per approach [3] | 6 s | 0.99 to 0.99999 | 1-8\times10^{-6} in any 15 s |

---

Euromed GNSS II national workshop, Alger, 13 June 2013
## EGNOS SoL Service performances (ECAC)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Accuracy</strong></td>
<td></td>
</tr>
<tr>
<td>Vertical Accuracy</td>
<td>4 meters (95% percentile)</td>
</tr>
<tr>
<td>Horizontal Accuracy</td>
<td>3 meters (95% percentile)</td>
</tr>
<tr>
<td><strong>Integrity</strong></td>
<td></td>
</tr>
<tr>
<td>Integrity Risk</td>
<td>$2 \times 10^{-7}$/approach</td>
</tr>
<tr>
<td>Time To Alert</td>
<td>Less than 6 seconds</td>
</tr>
<tr>
<td><strong>Availability</strong></td>
<td></td>
</tr>
<tr>
<td>Availability</td>
<td>99.9% for NPA in all the ECAC</td>
</tr>
<tr>
<td></td>
<td>99% for APV-I in most ECAC</td>
</tr>
<tr>
<td><strong>Continuity</strong></td>
<td></td>
</tr>
<tr>
<td>Continuity</td>
<td>For NPA:</td>
</tr>
<tr>
<td></td>
<td>$&lt; 2.5 \times 10^{-4}$ per hour in most of ECAC</td>
</tr>
<tr>
<td></td>
<td>$&lt; 2.5 \times 10^{-3}$ per hour in other areas</td>
</tr>
<tr>
<td></td>
<td>For APV-I:</td>
</tr>
<tr>
<td></td>
<td>$&lt; 1.0 \times 10^{-4}$ per 15 seconds in the core ECAC</td>
</tr>
<tr>
<td></td>
<td>$5 \times 10^{-4}$ per 15 seconds in most ECAC</td>
</tr>
<tr>
<td></td>
<td>$10 \times 10^{-3}$ per 15 seconds in other areas</td>
</tr>
</tbody>
</table>
## EUROCONTROL PBN Regulatory Approach Document (RAD) Consultation, 5 Feb 2013

<table>
<thead>
<tr>
<th>Date of applicability of certification and operational approval</th>
<th>PHASE OF FLIGHT</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Date of applicability of certification and operational approval for aircraft and implementation for Service Provider</td>
<td>Aircraft</td>
<td>Terminal</td>
</tr>
<tr>
<td>Above FL195</td>
<td>Below FL195</td>
<td>Service Provision</td>
</tr>
<tr>
<td>By end 2018</td>
<td></td>
<td></td>
</tr>
<tr>
<td>By end 2020</td>
<td></td>
<td></td>
</tr>
<tr>
<td>By end 2023</td>
<td>A.RNP + FRT</td>
<td>RNP1 + RNAV Holding</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
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</tbody>
</table>

Source: EUROCONTROL