Uso práctico de sistemas GNSS. Aplicaciones en el sector de la aviación.

Taller de capacitación técnica y operacional sobre sistemas globales de navegación por satélite.

Título ponencia: GNSS Monitoring

Organizado por:
GNSS Monitoring

GNSS Monitoring in Europe

G-Letter functionality
GNSS Monitoring

**GNSS Monitoring Service**

ICAO (ANNEX 10) recommends the recording and retention of GNSS data to those States that want to approve GNSS-based operations.

These recorded data are primarily intended for use in accident and incident investigations. They may also support periodic confirmation that accuracy, integrity, continuity and availability (the so-called Key Performance Indicators) are maintained within the limits required for the operations approved.

These recordings should be retained for a minimum period of 14 days, except if they are pertinent to accident and incident investigations, as in such case they should be retained until they are no longer required.

Due to this, and also to improve the service offered, many ANSP’s and airports managers are exploring possibilities of monitoring the GNSS signal.

However, most of the time the ANSPs face the following problems:

- Lack of internal expertise on GNSS monitoring
- No previous experience on GNSS monitoring
- Lack of internal resources for GNSS monitoring
GNSS Monitoring Service

GNSS Monitoring service allows fulfillment of ICAO Annex 10 recommendations for Legal Data Recording:

<table>
<thead>
<tr>
<th>ICAO Annex 10 monitoring parameters recommendation:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data must be collected at 1Hz (1 sample each second)</td>
</tr>
<tr>
<td>GPS and SBAS observed satellite Carrier-to-Noise density</td>
</tr>
<tr>
<td>GPS and SBAS observed satellite raw pseudo-range code and carrier phase measurements</td>
</tr>
<tr>
<td>Broadcast satellite navigation messages</td>
</tr>
<tr>
<td>Broadcast SBAS data messages</td>
</tr>
<tr>
<td>Relevant recording receiver status information</td>
</tr>
</tbody>
</table>

Source: Extract from ICAO Annex 10 documentation (Volume I)
GNSS Monitoring

Key Performance Indicators (KPI)

The performance of any GNSS system is measured through four different Key Performance Indicators: **Accuracy, Integrity, Continuity** and **Availability**.

Accuracy and Integrity are referred as local performance figures and are obtained at the monitoring stations. However, Availability and Continuity are considered global performance figures and are estimated at country’s / state’s level in order to avoid the results being affected by local effects.

<table>
<thead>
<tr>
<th>Key Performance Indicator</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Accuracy</strong></td>
<td>The GNSS position error is the difference between the estimated position and the actual position.</td>
</tr>
<tr>
<td><strong>Integrity</strong></td>
<td>The integrity is a measure of the trust that can be placed in the correctness of the information supplied by the total system. The necessary level of integrity for each operation is established with respect to specific horizontal and vertical protection levels and when the integrity estimates exceed these limits, the user should be alerted within the prescribed time period.</td>
</tr>
<tr>
<td><strong>Continuity</strong></td>
<td>Ability of a system to perform its function without (unpredicted) interruptions during the intended operation.</td>
</tr>
<tr>
<td><strong>Availability</strong></td>
<td>Ability of a system to perform its function at initiation of intended operation. System availability is the percentage of time that accuracy, integrity and continuity requirements are met.</td>
</tr>
</tbody>
</table>
**Key Performance Indicators (KPI): Accuracy**

The accuracy is measured by means of the Position Error (PE). It is the difference between the estimated position (position given by the receiver) and the actual position (exact position where the receiver is).

According to the ICAO SARPS at least 95% of the samples should be within the accuracy requirements for the given operation. The requirements defined for the APV-I operations are fixed at 16 m for the horizontal plane and 20 m in the vertical for 95% of the samples.

These requirements are translated to EGNOS Mission level where the EGNOS Mission Requirements Document (section 2.2.3.2.3.1.2) states that for the provision of EGNOS Safety of Life (SoL) service down to APV-1 the system accuracy in the position domain (with a 95% confidence level) shall be less than 16 m in the horizontal and 20 m in the vertical domain.
Key Performance Indicators (KPI): Accuracy

As shown in this graphic, the mean value for the position error is 0.567 m; while the 95% of the samples have an error lower or equal than 1.01 m.

- If the Position Error in a given sample was greater than 10 m an anomaly occurs (outlier). This should be detected and analyzed.
- If the 95% Position Error was greater than 16 m (in horizontal) or 20 m (in vertical), a percentile outlier occurs. This should be detected and analyzed.
Key Performance Indicators (KPI): Integrity

The integrity is a measure of the trust that can be placed in the correctness of the information supplied by the total system. The integrity performance of the service is specified as an integrity risk; i.e. the occurrence probability for any user of being affected by a position error larger than the alert limits and the system failing to warn the user within the time-to-alert (TTA) period of time.

According to the ICAO SARPS the integrity risk for APV-I operations shall be less than 2x10-7 per approach with time to alert of 10 seconds.

The integrity performance is measured by means of the Safety Index (SI), which is the ratio between the Position Error and the Protection Level (SI = PE/PL).

- If the PE is lower than the PL we are in a nominal and normal case. For example if we have an error of 0.5 m and a PL of 12 m the SI will be: SI = 0.5/12 = 0.041666
- If the PE is greater than the PL, there is an integrity event. For example if we have an error of 12.1 m and a PL of 12 m the SI will be: SI = 12.1/12 = 1.008333
Key Performance Indicators (KPI): Integrity

Time Plot:
Position Error and Protection Level plot during the whole timeframe

Stanford Plot:
Position Error vs Protection Level plot
Upper ➔ Horizontal domain
Lower ➔ Vertical domain

As shown in this graphic, the mean value for the Safety Index is 0.0215; while the maximum value is 0.11.

• If any sample was greater than 1 an integrity event occurs. This should be detected and analyzed.
Key Performance Indicators (KPI): Continuity

The continuity is the ability of a system to perform its function without (unpredicted) interruptions during the intended operation. In other words, the continuity of a system is the capability of the total system to perform its function without nonscheduled interruptions during the intended operation.

How does react a certified receiver on a discontinuity event?

- If service interruption occurs after the IAF, but before the FAF, the procedure can be continued until the FAF with a service downgrade (GPS-NPA). SBAS service shall be reestablished previous to FAF.
- If service interruption occurs after the FAF, a missed approach must be started. Operation can be restarted (from the IAF) whenever SBAS service operation is restored.
Key Performance Indicators (KPI): Availability

The availability of a system is the percentage of time that the system is performing a required function under stated conditions. Availability is an indication of the ability of the system to provide usable service within the specified coverage area.

Linked to the previous indicator: Availability is the ability of the system to provide usable service while Continuity is the capability to maintain that service during the intended operation.

100% >= Availability >= 99% : blue
99% > Availability >= 98% : green
98% > Availability >= 95% : yellow
Availability <  95% : red
Index

GNSS Monitoring

GNSS Monitoring in Europe

G-Letter functionality
The EGNOS case

As an example of GNSS monitoring, the EUROCONTROL EGNOS Data Collection Network is presented in this section.

49 receivers:

- 22 GPS/EGNOS
- 14 SBAS/GPS/Galileo
- 13 TSO 145-146 receivers
GNSS Monitoring in Europe

The EGNOS case

The GNSS Monitoring service provided by the EDCN is composed by:

- A **Data Collection Platform**, which collects raw data from GNSS receivers allowing the fulfillment of ICAO Annex 10 recommendations for Legal Data Recording. All the collected data is stored both in the local computer and a global database.

- A **Data Visualization Webtool**, which allows the visualization of the EGNOS performances together with an anomaly detection which eases the search and the analysis of any produced anomaly.
Data visualization webtool

Provides an automatic GNSS performances analysis, reporting and anomaly assessment in an easy-to-use environment

Selected stations for the visualization of performances

Geostationary satellite selected for the analysis (PRN120 and PRN126 currently in operation in Europe)

Period of time to be represented
Data visualization webtool: Accuracy

Provides information on accuracy performances during the specified timeframe and PRN.

The statistical values presented in the table characterize the combined error distribution for all sites together during the data collection period. The maximum value is the highest value measured in the whole set of stations, regardless of the geographical location.

95% percentil of the Position Error in both Horizontal and Vertical domain for each of the selected stations.

Accuracy histogram for the selected stations altogether and for the specified timeframe.
GNSS Monitoring

Data visualization webtool: Integrity

Provides information on the integrity performances during the specified timeframe and PRN.

The statistical values presented in the table characterize the combined safety index distribution for all sites together during the data collection period. The maximum value is the highest value measured in the whole set of stations, regardless of the geographical location.

95% percentil of the Position Error in both Horizontal (blue) and Vertical (yellow) domain for each of the selected stations.

Accuracy histogram for the selected stations altogether and for the specified timeframe. In the Horizontal (left) and Vertical (right) domain

Stanford plot in the Horizontal (left) and Vertical (right) domain for the selected stations altogether and for the specified timeframe.
GNSS Monitoring

Data visualization webtool: Continuity

Provides information on continuity of service during the specified timeframe and PRN

<table>
<thead>
<tr>
<th>Continuity plot accumulated for the period</th>
<th>Combined Continuity plot accumulated for the period</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="EGNOS APV-1 continuity risk map" /></td>
<td><img src="image2" alt="EGNOS APV-1 continuity risk map" /></td>
</tr>
</tbody>
</table>

Continuity risk <= $10^{-4}$ : blue
$10^{-4}$ < Continuity risk <= $5 \times 10^{-4}$ : light blue
$5 \times 10^{-4}$ < Continuity risk <= $10^{-3}$ : green

EGNOS APV-1 continuity risk map over the EGNOS Coverage Area for the selected timeframe and PRN

EGNOS APV-1 continuity risk map over the EGNOS Coverage Area for the selected timeframe and for the PRN combined solution (GEO-switching)
 GNSS Monitoring

Data visualization webtool: Availability

Provides information on availability of signal during the specified timeframe and PRN

SIS Availability histogram per day during the specified timeframe

100% >= Availability >= 99% : blue
99% > Availability >= 98% : green
98% > Availability >= 95% : yellow
Availability < 95% : red

EGNOS APV-1 availability map over the EGNOS Coverage Area for the selected timeframe and PRN

EGNOS APV-1 availability map over the EGNOS Coverage Area for the selected timeframe and for the PRN combined solution (GEO-switching)
# GDCN: Future

## GNSS new functionalities for EDCN 2013

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>G-LETTER*</td>
<td>GPS NPA</td>
</tr>
<tr>
<td>LPV200*</td>
<td>EDAS</td>
</tr>
<tr>
<td>MOPS Real-time*</td>
<td>Real-time monitoring</td>
</tr>
<tr>
<td>Improve Service Quality</td>
<td>Full Raw-data recording</td>
</tr>
</tbody>
</table>

## GNSS new functionalities for EDCN 2014

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>RNP/RNAV</td>
<td>GALILEO</td>
</tr>
</tbody>
</table>

## Objective

Evolve the current EGNOS Data Collection Network towards a GNSS Data Collection Network

* Functionalities already available

The GNSS Data Collection Network is alive and evolving in line with user’s new requirements
## Why GDCN?

### Characteristics
- Monitoring network
- Available to any country
- Data logging 24/7 basis
- Automatic data analysis and reporting, 24/7
- KPI performances monitoring
- Compliant with SARPS

### Advantages
- Used for EGNOS Service Provision acceptance
- Total visibility
- Cost-effective
- Upgradable upon requirements of EUROCONTROL, EC and users
- Evolving towards GNSS Monitoring Service

---

EDCN is the better option of GNSS Monitoring service and is freely offered by EUROCONTROL.
GDCN: Future - GLetter

- Allows the ANSP to generate its own GNSS performance report, based on the GNSS stations deployed in its country
- Can be adapted to any country particularities and needs
- Any country can benefit from GDCN (and G-Letter)
- This G-Letter example is based on EGNOS performances (APV-I and LPV200). However, it is extended to any other GNSS performances (GPS-NPA, other SBAS systems, ...)

PBN (GNSS) Workshop 25th – 26th April, 2013
The advantages of the G-Letter are:

- Customized report for each ANSP
- Visibility of global and local performances
- Possibility to save the desired queries for future consultation
- Printable in report format
GDCN: Future - GLetter

EUROCONTROL DATA COLLECTION NETWORK

Table of contents

1. Performance summary
2. Detailed global performance
   2.1 EGNOS performance for PRN120
   2.2 EGNOS performance for PRN126
   2.3 EGNOS combined performance with PRN120 and PRN126
3. Detailed local performance
   3.1 EDCN performance for PRN120
   3.2 EDCN performance for PRN126
   3.3 Events and anomalies detected

Annex
A.1 The EUROCONTROL Data Collection Network
A.2 Key Performance Indicators for performance monitoring

http://edcn3.pildo.com/
Usr/pwd: gdcn/workshop
In order to have access the G-Letter generation, please contact Pildo Labs if:

- You have stations connected to the EDCN and you want to generate performance reports. Pildo Labs will enable the G-Letter generator and include the ANSP’s logo

- You want to include stations to the EDCN. Pildo Labs will provide receiver deployment support and create a user to access the EDCN web and G-Letter

- You don’t have a station connected to the EDCN and you want to try the G-Letter with Pildo Labs’ station. Pildo Labs will provide a temporary user/password
GDCN: Future – Real Time

Available for Mobile phones too!!
No part of this material may be copied, reproduced and/or disclosed, in any form or by any means without the prior written permission of the Pildo Labs (contact@pildo.com). © 2012

This material reflects only the author’s views and the company is not liable for any use that may be made of the information contained herein.