The Use of Satellite Navigation in Aviation: Towards a Multi-Constellation and Multi-Frequency (MCMF) GNSS Scenario

- Satellite navigation systems in aviation
- GNSS as a Communications, Navigation and Surveillance (CNS) element
- An IFR flight profile
- MCMF avionics – GNSS sensors
- Challenges raised by MCMF GNSS
- Mitigation of GNSS vulnerabilities in aviation
- Evolution of the air navigation infrastructure
Satellite navigation systems in aviation (I)

Cumulative core revenue (%) - 2013-2023

Note: core revenues refer to the value of only GNSS chipsets in a device.

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**GNSS Concept**

**GNSS constellations**
- GPS
- Galileo
- GLONASS
- BeiDou

**GBAS (Ground Based Augmentation System)**

**SBAS (Satellite Based Augmentation System)**
- WAAS
- EGNOS
- MSAS
- GAGAN

**ABAS (Aircraft Based Augmentation System)**

**RAIM and Inertial systems**

**ICAO standards.**
GNSS as a Communications (C), Navigation (N) and Surveillance (S) element

Source: EUROCONTROL
An IFR flight profile:

- Departure
- En-route
- Arrival
- Instrument Approach

Airports:
- Airport A
- Airport B
MCMF avionics – GNSS sensors (I)

Capability of GNSS receivers – Aviation segment

Supported constellations by receivers – Aviation segment

MCMF GNSS will enhance the performances and robustness of GNSS, but…

There are challenges to be sorted out:

- Institutional
- Technical
Institutional challenges

- Currently States do preclude and/or approve some specific constellations within their airspaces.

- ICAO has proposed to assess practical solutions, e.g. MCMF avionics to automatically select or deselect a given constellation to navigate seamlessly over airspaces where constellations are either approved or precluded.

  - However, such a switching function might not be justified for en-route and terminal operations, but only for final approach and landing.

  - …on-going discussions at the ICAO Navigation Systems Panel (NSP).
Institutional challenges

How to handle the constellation approval status at avionics level?

2025 situation

- GPS + Galileo
- GPS only
- GPS + GLONASS
- GPS + BeiDou

2040 situation: a dream?

- GPS + GLONASS + BeiDou + Galileo

Source: EUROCONTROL
Challenges raised by MCMF GNSS (IV)

Technical challenges

- Key to ensure compatibility and interoperability
  - Standards and Recommended Practices (SARPS) in ICAO Annex 10, Volume I.

- GNSS vulnerabilities
  - GNSS signal disruption might affect multiple aircraft over a wide area;
  - MCMF GNSS will help mitigate interference,…however
  - Disruption cannot be completely ruled out;
    - Air Navigation Service Providers (ANSPs) must be prepared to deal with potential loss or degradation of GNSS signals.
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Challenges raised by MCMF GNSS (V)

…it might happen that GNSS is degraded, disrupted on unable to support the on-going flight operation.
Monitoring and alerting in the cockpit

MCDU

Source: EUROCONTROL
Disruption of GNSS requires realistic and effective mitigation techniques

Three main methods (can be applied in combination):

- Taking advantage of on-board equipment, particularly Inertial Navigation Systems;

- Taking advantage of conventional navigation aids (such as Distance Measuring Equipment and Instrument Landing System), and radar; and

- Employing procedural (aircrew and/or Air Traffic Control) methods.

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Evolution of the air navigation infrastructure

<table>
<thead>
<tr>
<th>NAVIGATION</th>
<th>2018</th>
<th>2023</th>
<th>2028</th>
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<tbody>
<tr>
<td><strong>Enablers</strong></td>
<td></td>
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<tr>
<td>Conventional</td>
<td>ILS/MLS</td>
<td>Retain to support precision approach and to mitigate GNSS outage</td>
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<tr>
<td>Satellite-based</td>
<td>Core GNSS Constellations</td>
<td>Single frequency (GPS/GLONASS)</td>
<td>Multi-Freq/Multi-Constellation (GPS/GLONASS/Beidou/Galileo)</td>
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<td>Source: ICAO Doc 9750</td>
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**PBN Operations**
- B0-APTA, B0-CDO, B0-FRTO
- B1-FRTO, B1-TBO
- B2-CDO
- B3-TBO, B3-NOPS

**Precision Approach**
- CAT I/II/III Landing
  - ILS/MLS
  - GBAS Cat I
  - Cat I/II/III SBAS LPV 200

- B0-APTA
- B1-APTA

Source: ICAO Doc 9750
Thanks for your attention

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