ABOUT IFALPA

► Approaching 100 Member Associations world-wide
► In excess of 100,000 pilot members
► IFALPA Headquarters in Montreal, close to ICAO
► ´Observer´ status with ICAO >> access and participation!

https://www.ifalpa.org/about-us/
GPS and GNSS in aviation

The Minimum Equipment List: Complex interrelationships

ICAO SWx Advisories, Space Wx and an EGNOS System fault

Jamming and Spoofing

Conclusion
GPS / GNSS in aviation
Takeoff: 100% manual, no GNSS use - except, finding the runway with a moving map display...
Flying? A huge number of GPS / GNSS uses, all using single system, single frequency receivers.

Tabular Summary of Reversion Scenario 1
(NORMAL OPERATIONS, adapted from the doc)

<table>
<thead>
<tr>
<th>REVERSION INFRASTRUCTURE</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Available Navaid Infrastructure</td>
<td>GPS; SBAS/GBAS; DME/DME; VOR/DME; ILS</td>
</tr>
<tr>
<td>Fleet Positioning Capability for PBN</td>
<td>GPS + D/D &gt; 90% + VOR/DME (10% can only do conventional); ILS; SBAS/GBAS 20%</td>
</tr>
<tr>
<td>Surveillance Sensors Used</td>
<td>PSR; MULTIPLE SSR; with ADS-B or MLAT</td>
</tr>
<tr>
<td>Communication Service Used</td>
<td>Voice; Data Link</td>
</tr>
<tr>
<td>Timing for On-Board Systems</td>
<td>Independent + GPS synchronised</td>
</tr>
<tr>
<td>Timing for Ground Systems</td>
<td>Independent + GPS synchronised</td>
</tr>
</tbody>
</table>

https://www.icao.int/NACC/Documents/Meetings/2021/ADSB/P05-FutureADS-B-ENG.pdf
https://www.eurocontrol.int/publication/european-gnss-contingency-reversion-handbook-pbn-operations
SAFETY NETS - at least impaired, if not inoperative.

- **EGPSW**
  - Enhanced Ground Proximity Warning System

- **ACAS X**
  - Airborne Collision Avoidance System X (new)

- **RAAS**
  - Runway Awareness and Advisory System

- **ROPS**
  - Runway Overrun Prevention System

**Flying? Highly reduced**

- efficiency, capacity,
- SAFETY

if GPS (GNSS) is not available.

**Tabular Summary of Reversion Scenario 1**

<table>
<thead>
<tr>
<th>REVERSION INFRASTRUCTURE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Available Navaid Infrastructure</strong></td>
</tr>
<tr>
<td>GPS; SBAS/GBAS ; DME/DME; VOR/DME; ILS</td>
</tr>
<tr>
<td><strong>Fleet Positioning Capability for PBN</strong></td>
</tr>
<tr>
<td>GPS + D/D &gt; 90% + VOR/DME (10% can only do conventional); ILS; SBAS/GBAS 20%</td>
</tr>
<tr>
<td><strong>Surveillance Sensors Used</strong></td>
</tr>
<tr>
<td>PSR; MULTIPLE SSR; with ADS-B or MLAT</td>
</tr>
<tr>
<td><strong>Communication Service Used</strong></td>
</tr>
<tr>
<td>Voice; Data Link</td>
</tr>
</tbody>
</table>

Explanation: Whilst Data Link & MLAT may not be lost immediately, time de-synchronisation may occur in the longer term.

**Timing for On-Board Systems**

Independent + GPS synchronised

**Timing for Ground Systems**

Independent + GPS synchronised
IFALPA

GNSS milestone achieved as ICAO Council adopts new dual-frequency multi-constellation standards

Montréal, 23 March 2023 — The ICAO Council achieved a major milestone this week in the global standardization and roll-out of new dual-frequency multi-constellation (DFMC) capabilities for international aviation’s Global Navigation Satellite System (GNSS).

“This is an important development toward improving the safety, efficiency and sustainability of international air transport through more precise airspace management and more efficient routes and procedures,” emphasized Council President Salvatore Sciacchitano.

“Eventually these new standards will provide international aviation with access to an extensive global infrastructure and over 50 new GNSS satellites.”

DFMC GNSS permits the combined leveraging of dual frequency signals from up to four GNSS constellations simultaneously, including the GPS system (United States), Galileo (European Union), GLONASS (Russian Federation), and BeiDou (China).

Getting it certified, built and installed in airplanes in sizeable numbers will take decades.
The Minimum Equipment List : Complex interrelationships
Master Minimum Equipment List (MMEL)

Revision: 20
Date: 08/04/2020

Airbus SAS
A330-200 Series, A330-200 Freighter Series, A330-300 Series,
A330-800 Series, A330-900 Series
All Models
No ADS-B means Air Traffic Control receives no ADS-B position reports - a main input!!

<table>
<thead>
<tr>
<th>Sequence No.</th>
<th>Item</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>Change Bar</th>
</tr>
</thead>
<tbody>
<tr>
<td>34-58-01 ***</td>
<td>Satellite Navigation (Cont’d)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1)</td>
<td>Global Positioning System (GPS)</td>
<td>C</td>
<td>2</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b)</td>
<td>With Mod. 55661/MP S18779 (ADS-B OUT Function) compliant with DO260 or DO260B</td>
<td>C</td>
<td>2</td>
<td>0</td>
<td>(O)</td>
<td></td>
</tr>
</tbody>
</table>

(O) One may be inoperative provided alternate procedures are established and used.

(O) May be inoperative provided:

a) Navigation, approach and landing procedures are not based on the use of GPS, and
b) One DME is operative.

NOTE: If no GPS is available, ADS-B Squitter Transmissions are considered inoperative.
Master Minimum Equipment List (MMEL)

Revision: 4
Date: 05/01/2019

Airbus SAS
A350-900 Series, A350-1000 Series
All Models
Most accurate and efficient airspace and procedure design is based on GPS (GNSS). These airspaces and approach procedures cannot be used without GPS (GNSS) due to aircraft system inaccuracies and lacking capabilities.

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
<th>Status</th>
<th>Category</th>
<th>Limitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>34-50</td>
<td>Radio/GNSS Navigation Systems</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>34-50-01</td>
<td>GNSS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>34-50-01A</td>
<td>One GNSS inoperative (Aircraft without MP L41151/MOD 100422)</td>
<td>C 2 1</td>
<td>(O)</td>
<td>One may be inoperative.</td>
</tr>
<tr>
<td>34-50-01B</td>
<td>One GNSS inoperative (Aircraft with MP L41151/MOD 100422)</td>
<td>C 2 1</td>
<td>(O)</td>
<td>One may be inoperative provided that approach and landing procedures are not based on the use of the GLS and the SLS.</td>
</tr>
<tr>
<td>34-50-01C</td>
<td>Both GNSSs inoperative</td>
<td>C 2 0</td>
<td>(O)</td>
<td>Both may be inoperative provided that:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1) One DME is operative, and</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2) Navigation, approach, and landing procedures are not based on the use of the GNSS.</td>
</tr>
</tbody>
</table>
Master Minimum Equipment List

Revision: 12
Date: 09/30/2015

BOEING 787

James M. Eitel
Flight Operations Evaluation Board (FOEB)
Failure, or unusability of systems unrelated to GPS at first glance may have cross-dependencies in today's integrated avionics. Impossible to tell without lots of study which system can still be used.

<table>
<thead>
<tr>
<th>Date</th>
<th>Right Static Air Data Module</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>-12-02-01</td>
<td>B</td>
<td>1</td>
</tr>
</tbody>
</table>

May be inoperative provided:

- a) Left static air data module operates normally.
- b) Pitot air data modules operate normally,
- c) Pitot probe heater systems operate normally,
- d) AIR DATA/ATT instrument source switches operate normally,
- e) At least one GPS operates normally, and
- f) Approach minimums do not require its use.

(Continued)
EMBRAER HAS RECENTLY RECEIVED A REPORT OF GPS 1 AND 2 SIMULTANEOUS SIGNAL LOSS DURING FMS NAVIGATION IN CRUISE FLIGHT FOLLOWED BY A GPS HSI 1 AND 2 FAILURE INDICATION, ATTITUDE AND HEADING REFERENCE SYSTEM (AHRS) 1 AND 2 FAULT AND, AFTER A FEW MINUTES, A STALL WARNING PROTECTION SYSTEM (SWPS) FAULT, VENTRAL RUDDER FAIL, YAW DAMPER FAIL, AUTO PILOT FAIL, A N D CAS MESSAGES ASSOCIATED WITH UNEXPECTED ROLLING AND YAWING OSCILLATIONS (DUTCH ROLL) AT HIGH AIRSPEEDS.

FURTHER ANALYSIS REVEALED GPS CONSTELLATION SIGNAL INSTABILITY IN THE FLIGHT AREA LEADING TO LOSS OF BOTH GPS INFORMATION DATA AND CAUSING THE EVENT DESCRIBED ABOVE.

Note: this info on an extreme case is from 2016, and system behaviour should be improved today
ICAO SWx Advisories, Space Wx and an EGNOS System fault
ICAO Space Weather Advisory

Airline Pilots do not get the ICAO SWx advisories from their airlines despite clear ICAO and EASA §§.

https://ifalpa.org/publications/library/space-weather-advisories--3595
<table>
<thead>
<tr>
<th>SWx Advisory</th>
<th>Inflight / en-route</th>
<th>Dispatch / before departure</th>
</tr>
</thead>
<tbody>
<tr>
<td>GNSS MOD</td>
<td>- check means of navigation (DME-updating, IRS, VOR)</td>
<td>- check means of navigation (DME-updating, IRS, VOR), incl. MEL</td>
</tr>
<tr>
<td></td>
<td>Check RNAV/RNP-Capability and requirements</td>
<td>Check RNAV/RNP-Capability and requirements</td>
</tr>
<tr>
<td></td>
<td>- check if conventional approach procedures at destination and alternate can be</td>
<td>- check if conventional approach procedures at destination and alternate can be used &amp;</td>
</tr>
<tr>
<td></td>
<td>used &amp; plan accordingly</td>
<td>plan 2\textsuperscript{nd} alternate</td>
</tr>
<tr>
<td></td>
<td>- consider adding 30 min contingency fuel for unforeseen events, e.g. airspace</td>
<td>- consider including 1hr contingency fuel for unforeseen events e.g. airspace-closures</td>
</tr>
<tr>
<td></td>
<td>closures</td>
<td>- consider flight cancellation</td>
</tr>
<tr>
<td>GNSS SEV</td>
<td>- check means of navigation (DME-updating, IRS, VOR)</td>
<td>- check means of navigation (DME-updating, IRS, VOR), incl. MEL</td>
</tr>
<tr>
<td></td>
<td>- check if conventional approach procedures at destination and alternate can be</td>
<td>- check if conventional approach procedures at destination and alternate can be used &amp;</td>
</tr>
<tr>
<td></td>
<td>used &amp; plan accordingly</td>
<td>plan 2\textsuperscript{nd} alternate</td>
</tr>
<tr>
<td></td>
<td>- assure availability of planned route / RNAV/RNP</td>
<td>- check airspace and route availability (RNAV/RNP)</td>
</tr>
<tr>
<td></td>
<td>- consider diversion &amp; landing at en-route airport</td>
<td>- consider including 1hr contingency fuel for unforeseen events e.g. airspace-closures</td>
</tr>
</tbody>
</table>

Pilots’ suggestions on usage of ICAO SWx advisories.

Background on European Cockpit Association Website.

Note: Official procedures are not known - do they exist??

SBAS WAAS was disturbed by Space Weather.

In the Canadian reporting system, a case of 4 aircraft losing WAAS approach capability simultaneously was found.
SBAS EGNOS coverage / availability was reduced on 05 Oct 2023.

Space Weather was quiet- probably, an ionospheric disturbance. No details known.
05 Oct 2023

SW-Europe

lost

EGNOS due
to

Space Wx.
System fault: EGNOS declared all GPS satellites unusable on 09 Oct 23, for approx 1 hr total.

This Service Notice informs EGNOS SoL and OS users that the Signal in Space (SIS) from the Geostationary (GEO) satellites broadcasting the EGNOS SoL and OS services (PRN123 and PRN136) has presented an unstable behaviour during two periods on 09/10/2023, from 11:41 to 12:00 UTC and from 12:21 to 12:51 UTC. During multiple intervals within these periods, EGNOS declared all the GPS satellites as not usable (UDRE=15 "Do not Use"), causing some short and intermittent losses of service in the whole EGNOS service area. Since this last period, the EGNOS services are back to the normal situation.

The cause of this temporary unavailability has been identified and the necessary operational measures have been implemented to restore the service.
Jamming and Spoofing
Example of an official Notice To Airman, NOTAM, on possible GPS WAAS, GBAS and ADS-B unavailability

KZDV  DENVER (ARTCC), CO. [Back to Top]

10/032 (A0556/23) - NAV GPS (WSMRNM GPS 23-32) (INCLUDING WAAS, GBAS, AND ADS-B) MAY NOT BE AVBL WI A 349NM RADIUS CENTERED AT 333135N1063448W (TCS054038) FL400-UNL, 297NM RADIUS AT FL250, 234NM RADIUS AT 10000FT, 234NM RADIUS AT 4000FT AGL, 161NM RADIUS AT 50FT AGL. DLY 1830-2230. 20 OCT 18:30 2023 UNTIL 04 NOV 22:30 2023. CREATED: 15 OCT 18:23 2023
Example of an official Notice To Airman, NOTAM, on GPS Jamming

A0639/23 - 1-ALL AIRLINES FLYING THROUGH BAGHDAD FIR-ORBB SHOULD EXPECT GPS JA MMING/GNSS INTERFERENCE IN THE NORTHERN PART OF IRAQ ALONG THE ATS ROUTE UM688 FROM RATVO TO VAXEN.

2-ALL AIRLINES WITH DESTINATION ORER SHOULD EXPECT GPS JAMMING/GNSS INTERFERENCE DURING FINAL APPROACH PHASES.

3-PILOTS ARE EXPECTED TO INFORM THE RELEVANT ATS UNIT IN THE EVENT OF GPS SIGNAL OUTAGE IN ORDER TO REPORT IT TO THE CONCERNED AUTHORITIES AND TAKE THE APPROPRIATE ACTION TO ENSURE THAT ALL FLIGHT OPERATIONS ARE CARRIED IN SAFE AND EFFICIENT MANNER. 05 AUG 00:00 2023 UNTIL 04 NOV 23:59 2023. CREATED: 03 AUG 09:27 2023

IATA, the airlines’ association, is very concerned about harmful interference to GNSS.

Some GNSS/GPS Interference Hot Spots: 2019-2020

Two major clusters were observed:

- Eastern Turkish airspace to Iraq, Iran, Armenia (extended to border between Armenia and Azerbaijan)
- Southern Cypriot airspace to Egypt, Lebanon and Israel (extended to a corridor between Israel and Jordan)

Notably, these clusters locate around the Syrian airspace, where there is no regular civil operation.

**Topic:** Harmful Interference to Global Navigation Satellite System (GNSS) and its impacts on flight and air traffic management operations

**Introduction**

Global Navigation Satellite System (GNSS) includes navigation satellite infrastructures and constellations which provide position and timing information supporting aircraft and air traffic management operations.
Disruption of Satellite-Based Signals

BACKGROUND

Modern air traffic relies heavily on the internal accuracy of aircraft systems and the aircraft's ability to monitor its own reliability. In recent years, satellite-based Communication, Navigation and Surveillance (CNS) services have been taking a growing part in the overall ATM system and aircraft are becoming more reliant on space-based signals. The accuracy achieved by these signals enables aircraft to perform instrument procedures without the need to rely on ground-based navigational aids, facilitates the reduction of separation by ATC, and helps optimizing airspace capacity. Many aircraft navigation and warning systems rely heavily on accurate position.

In recent years, however, thousands of occurrences of partial or complete loss of these signals have been reported by pilots in different Regions, with interruptions generally lasting 10 to 20 minutes. This very serious concern was raised last year at the 40th ICAO Assembly and has led to three IFALPA Safety Bulletins:

- https://www.ifalpa.org/media/3388/19sab05-loss-of-gps-signal-at-ben-gurion.pdf, warning about GPS interference in TEL AVIV FIR, affecting LLBG. The phenomenon spread afterwards to NICOSIA FIR also and affected LCLK. GPS signal jamming and spoofing occurs also above Turkey, the Black Sea, and other regions in the Middle East;

IFALPA has continuously voiced concern and alarm about GPS / GNSS interference and effects on safety since many years!
Latest twist: not just jamming, but SPOOFING is observed. Aircraft navigation- and safety net systems are disrupted.

GPS Spoofing

NOTE: For IFALPA’s Position on Disruption of Satellite-based signals, see #21POS07.

IFALPA has been made aware of potential spoofing activities reported by various civil air operators in Iraq and Azerbaijan. Such activities can pose a significant risk to flight safety. IFALPA recommends that pilots operating in these Regions check local NOTAMs, put additional emphasis on maintaining continuous communications with appropriate ATC authorities, and monitor aircraft equipment performance closely for any discrepancies or anomalies. Pilots should also be prepared to operate without GPS navigational systems.
An example of a private company that provides satellite surveillance on GPS jammers and other emitters - globally.

Source: AerospaceAmerica, 3 / 2023

(Note: Not an endorsement, just info.)
GPS and GNSS in aviation
The Minimum Equipment List: Complex interrelationships
ICAO SWx Advisories, Space Wx and an EGNOS System fault
Jamming and Spoofing

Conclusions: Future usability of GPS / GNSS in Aviation is under threat:
- SWx impacts SBAS
- ICAO SWx advisories are not distributed properly
- ICAO SWx advisories in need of improvements (SBAS...)
- Jamming at many locations of the globe
- New threat: spoofing.

Actual and planned dependence on GPS and GNSS may have gone too far already.

My conclusion: We need to seriously look at APNT!
Thank you

Klaus Sievers    Klaus.Sievers@VCockpit.de

@ifalpa  www.ifalpa.org  facebook.com/ifalpa