



GNSS: Aviation Users' View

Klaus Sievers

Member, IFALPA ATS Committee

UNOOSA Workshop, Helsinki, 26 Oct 2023



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...**



SAFETY NETS

- **EGPSW**
Enhanced Ground Proximity Warning System
- **ACAS X**
Airborne Collision Avoidance System
- **RAAS**
Runway Awareness and Advisory System
- **ROPS**
Runway Overrun Prevention System



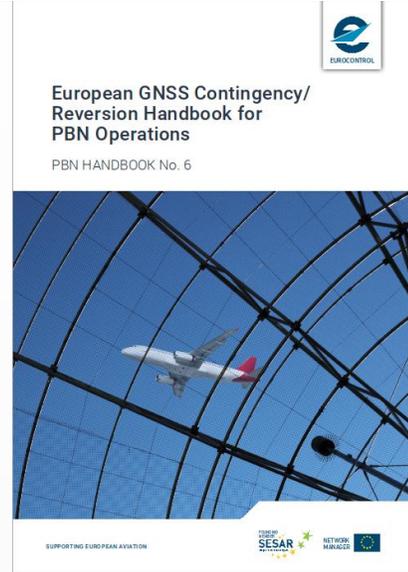
Flying ? A huge number of GPS / GNSS uses, all using single system, single frequency receivers .

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

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

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.

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Surveillance Sensors Used	PSR; MULTIPLE SSR; with ADS-B or MLAT
Communication Service Used	Voice; Data Link
<i>Explanation: Whilst Data Link & MLAT may not be lost immediately, time de-synchronisation may occur in the longer term.</i>	
Timing for On-Board Systems	Independent +GPS synchronised
Timing for Ground Systems	Independent +GPS synchronised

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).

Equipment of the new DFMC standard will alleviate some issues.

Getting it certified, built and installed in airplanes in sizeable numbers will take decades.



The Minimum Equipment List : Complex interrelationships



U.S. Department of Transportation
Federal Aviation Administration
Washington, DC

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



AIRCRAFT:
Airbus A330

TABLE KEY

1. REPAIR CATEGORY
2. NO. INSTALLED
3. NO. REQUIRED FOR DISPATCH
4. REMARKS OR EXCEPTIONS

34. Navigation

Sequence No.	Item	1	2	3	4	Change Bar
34-58-01 ***	Satellite Navigation (Cont'd)					
1)	Global Positioning System (GPS) (Cont'd)					
b)	With Mod. 55661/ MP S18779 (ADS-B OUT Function) compliant with DO260 or DO260B	C	2	1	(O) One may be inoperative provided alternate procedures are established and used.	
		C	2	0	(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.	

No ADS-B
means
Air Traffic Control
receives no
ADS-B position
reports -
a main input !!



U.S. Department of Transportation
Federal Aviation Administration
Washington, DC

Master Minimum Equipment List (MMEL)

Revision: 4
Date: 05/01/2019

Airbus SAS
A350-900 Series, A350-1000 Series
All Models



34-50	Radio/GNSS Navigation Systems				
34-50-01	GNSS				
34-50-01A	One GNSS inoperative (Aircraft without MP L41151/ MOD 100422)	C	2	1	(O) One may be inoperative.
34-50-01B	One GNSS inoperative (Aircraft with MP L41151/ MOD 100422)	C	2	1	(O) One may be inoperative provided that approach and landing procedures are not based on the use of the GLS and the SLS.
34-50-01C	Both GNSSs inoperative	C	2	0	(O) Both may be inoperative provided that: <ol style="list-style-type: none"> 1) One DME is operative, and 2) Navigation, approach, and landing procedures are not based on the use of the GNSS.

Most accurate and efficient airspace and procedure design is based on GPS (GNSS). These airspaces and approach procedures can not be used without GPS (GNSS) due to aircraft system inaccuracies and lacking capabilities.



U.S. Department of Transportation
Federal Aviation Administration
Washington, D.C.

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.

-12-02-01	Right Static Air Data Module	B	1	0	<p>May be inoperative provided:</p> <ul style="list-style-type: none"> 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)					


TELEGRAPHIC MESSAGE

Federal Aviation Administration 800 Independence Avenue, SW Washington, DC 20591	PRECEDENCE: PRIORITY
ACCOUNTING CLASSIFICATION	ACTION: PRIORITY
FOR INFORMATION	DATE PREPARED: 14 APRIL 2016
NAME	CALL
	PHONE NUMBER

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, AND 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



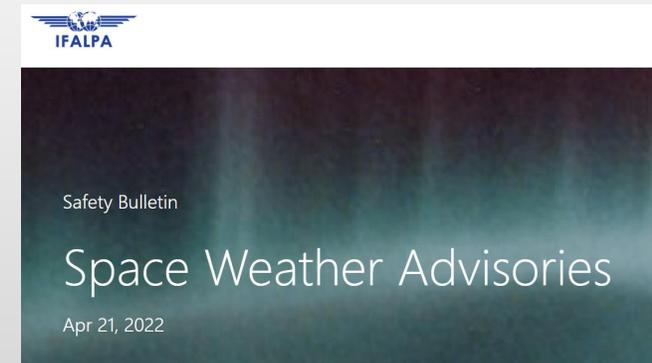
ICAO SWx Advisories, Space Wx and an EGNOS System fault



ICAO Space Weather Advisory

🕒 2022-11-07 15:36:00
FNXX01 EFKL 071535
SWX ADVISORY
DTG: 20221107/1536Z
SWXC: PECASUS
ADVISORY NR: 2022/57
NR RPLC: 2022/56
SWX EFFECT: GNSS SEV
OBS SWX: 07/1517Z HNH HSH W105 - E135
FCST SWX +6 HR: 07/2200Z NOT AVBL
FCST SWX +12 HR: 08/0400Z NOT AVBL
FCST SWX +18 HR: 08/1000Z NOT AVBL
FCST SWX +24 HR: 08/1600Z NOT AVBL
RMK: SPACE WEATHER EVENT (IONOSPHERIC
DISTURBANCE) IN PROGRESS. IMPACT ON GNSS PERFORMANCE
POSSIBLY LEADING TO LOSS OF GNSS SIGNALS AND/OR DEGRADATION
OF TIMING AND POSITIONING PERFORMANCE.
NXT ADVISORY: WILL BE ISSUED BY 20221107/2117Z=

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





SWx Advisory	Inflight / en-route	Dispatch / before departure
GNSS MOD	<ul style="list-style-type: none"> - check means of navigation (DME-updating, IRS, VOR) <p>Check RNAV/RNP-Capability and requirements</p> <ul style="list-style-type: none"> - check if conventional approach procedures at destination and alternate can be used & plan accordingly 	<ul style="list-style-type: none"> - check means of navigation (DME-updating, IRS, VOR), incl. MEL <p>Check RNAV/RNP-Capability and requirements</p> <ul style="list-style-type: none"> - check if conventional approach procedures at destination and alternate can be used & plan 2nd alternate - consider adding 30 min contingency fuel for unforeseen events, e.g. airspace closures
GNSS SEV	<ul style="list-style-type: none"> - check means of navigation (DME-updating, IRS, VOR) - check if conventional approach procedures at destination and alternate can be used & plan accordingly - assure availability of planned route / RNAV/RNP - consider diversion & landing at en-route airport 	<ul style="list-style-type: none"> - check means of navigation (DME-updating, IRS, VOR), incl. MEL - check if conventional approach procedures at destination and alternate can be used & plan 2nd alternate - check airspace and route availability (RNAV/RNP) - consider including 1hr contingency fuel for unforeseen events e.g. airspace-closures - consider flight cancellation

Pilots' suggestions on usage of ICAO SWx advisories.

Background on European Cockpit Association Website.

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



Report:

2023Q0875

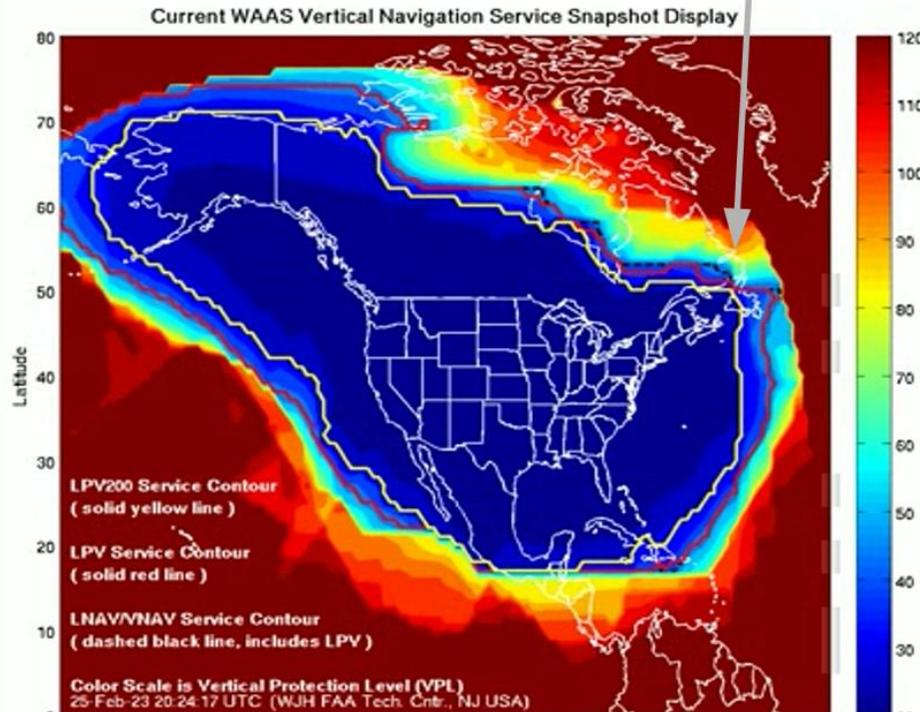
Date Entered:

2023-03-07

Narrative:

On approach for Runway 25 at Kuujuaq, QC (CYVP), an Exact Air Inc. Beech A100 (C-FLTS/ET823) from Tasiujaq, QC (CYTQ) to Kuujuaq, QC (CYVP) mentioned having lost the localizer performance with vertical guidance (LPV) in lateral navigation (LNAV) and during the previous approach for CYTQ. Following this, an Air Inuit Ltd. de Havilland DHC-8-314 (C-FIAI/AIE827) from Kangisualujuaq, QC (Georges River) (CYLU) to Kuujuaq, QC (CYVP) mentioned having the same problem when on approach for Runway 25. An Air Inuit Ltd. de Havilland DHC-6-300 (C-GTYX/AIE659) from Kangisujuaq, QC (Wakeham Bay) (CYKG) to Kuujuaq, QC (CYVP) that was following C-AIE827 had the same problem on approach for Runway 25 at CYVP and for its previous approach at CYKG.

Report: 25 Feb, 2020z
2023



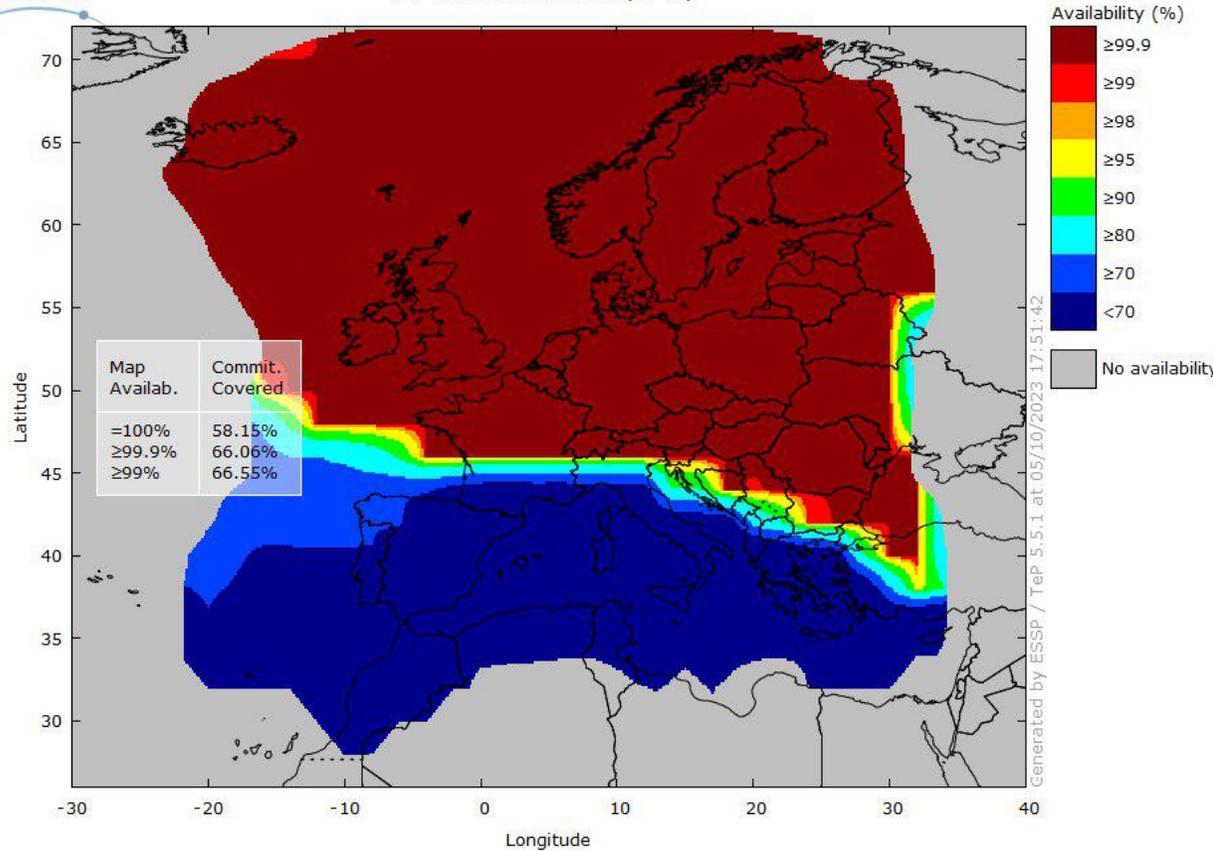
SBAS WAAS was disturbed by Space Weather.

In the Canadian reporting system, a case of 4 aircraft loosing WAAS approach capability simultaneously was found.



ESSP

SIS Op - 05/10/2023 16:45:00 to 05/10/2023 17:44:59
LPV200 Availability Map



SBAS EGNOS coverage / availability was reduced on 05 Oct 2023.

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



Toulouse Franczal

Airport Code: LFBF
HPL: 22.30 m
VPL: 39.44 m
Service status:

- LPV200: not available



Biarritz Bayonne Anglet

Airport Code: LFBZ
HPL: 25.55 m
VPL: 41.30 m
Service status:

- LPV200: not available



AS Madrid-Barajas

Airport Code: LEMD
HPL: 80.80 m
VPL: 102.83 m
Service status:

- LPV200: not available



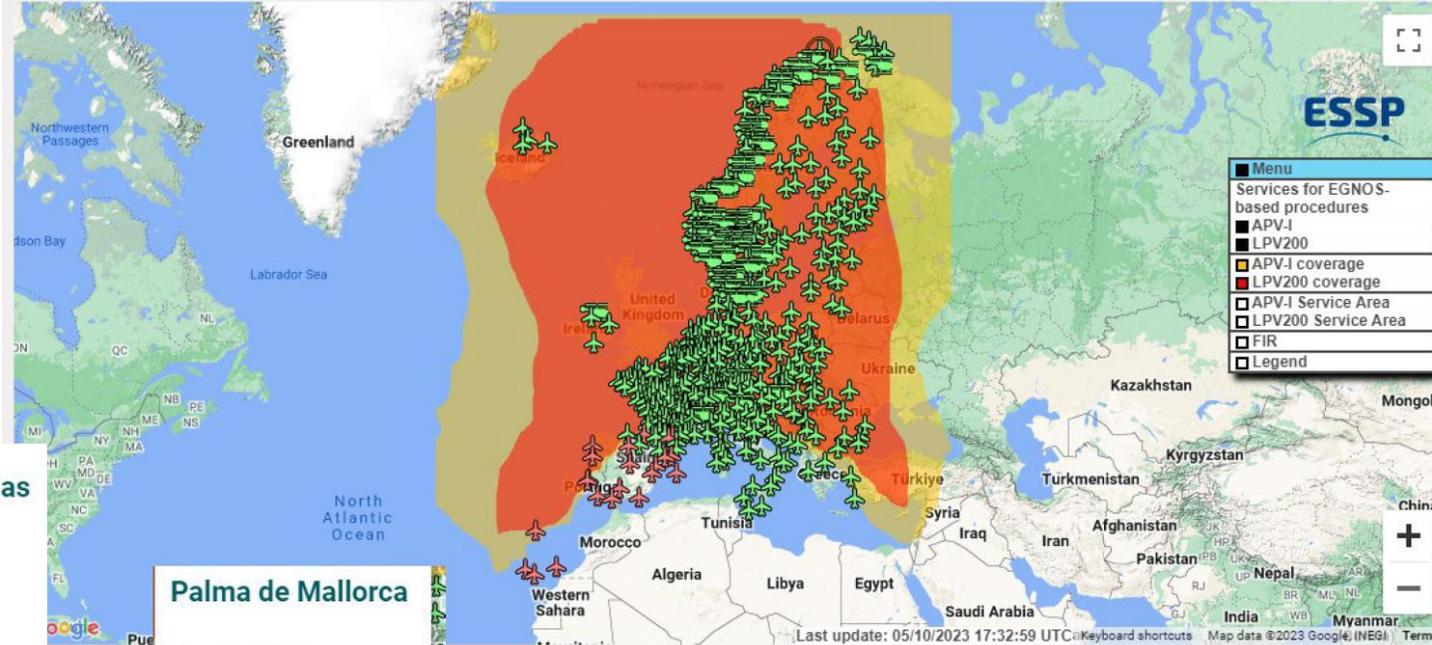
Palma de Mallorca

Airport Code: LEPA
HPL: 46.57 m
VPL: 59.69 m
Service status:

- APV-I: not available

LPV Availability at Airports [with SBAS-based procedures] (Real time)

This real time map shows LPV performance availability in the airports with APV-I, LPV200 and APV-Baro procedures based on SBAS. Click on an airport to see the HPL/VPL values and the applicable NOTAM proposals.



Last update: 05/10/2023 17:32:59 UTC Keyboard shortcuts Map data ©2023 Google (INEI) Terms

Country: ICAO: ANSP:

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.



The **EGNOS** Service Provider

EGNOS SERVICE NOTICE

Number: 028

Version: 1.0

To: EGNOS SoL and Open Service Users

Date: 10/10/2023

Subject: EGNOS Service temporary unavailability

Internal ESSP classification:

BLUE

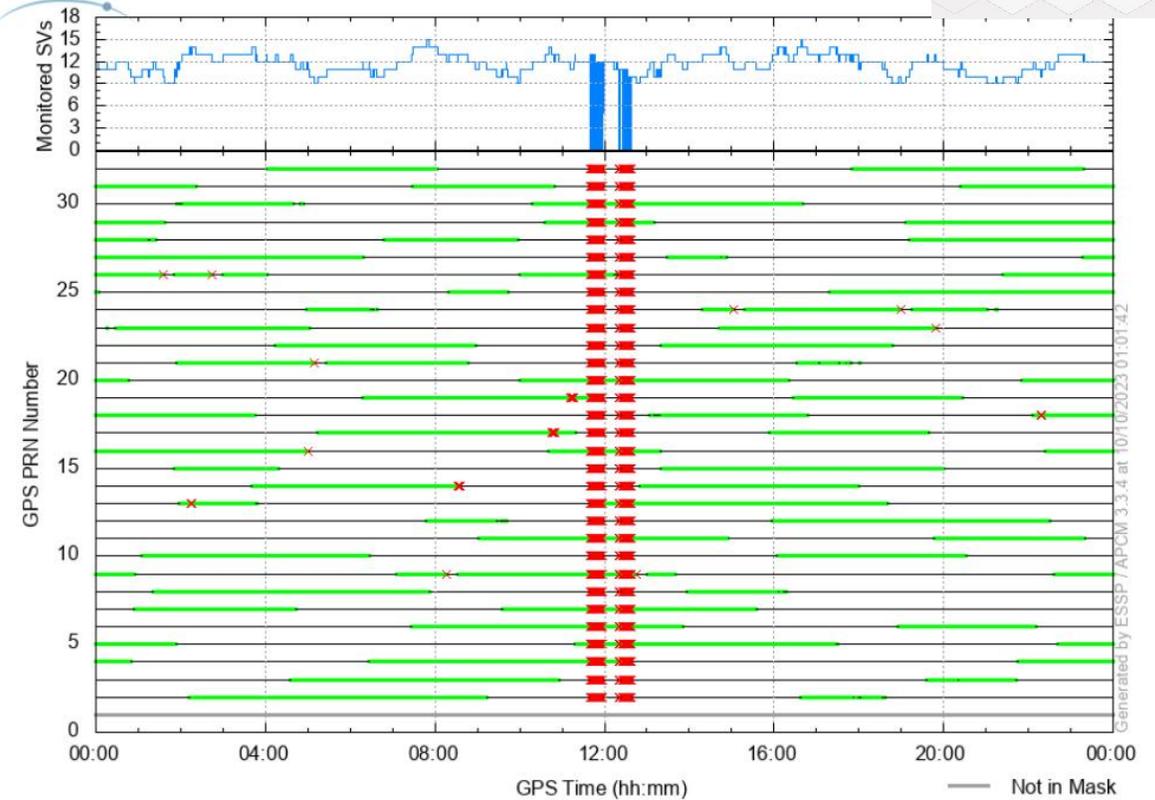
This Service Notice informs EGNOS SoL and OS users that the Signal in Space (SiS) from the Geostationary (GEO) satellites broadcasting the EGNOS SoL and OS services (PRN123 and PRN136) has presented an unstable behaviour during two periods on 09/10/2023, from 11:41 to 12:00 UTC and from 12:21 to 12:51 UTC. During multiple intervals within these periods, EGNOS declared all the GPS satellites as not usable (UDREI=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.



PRN 123 - 09/10/2023
SVs Status

EGNOS
User Support



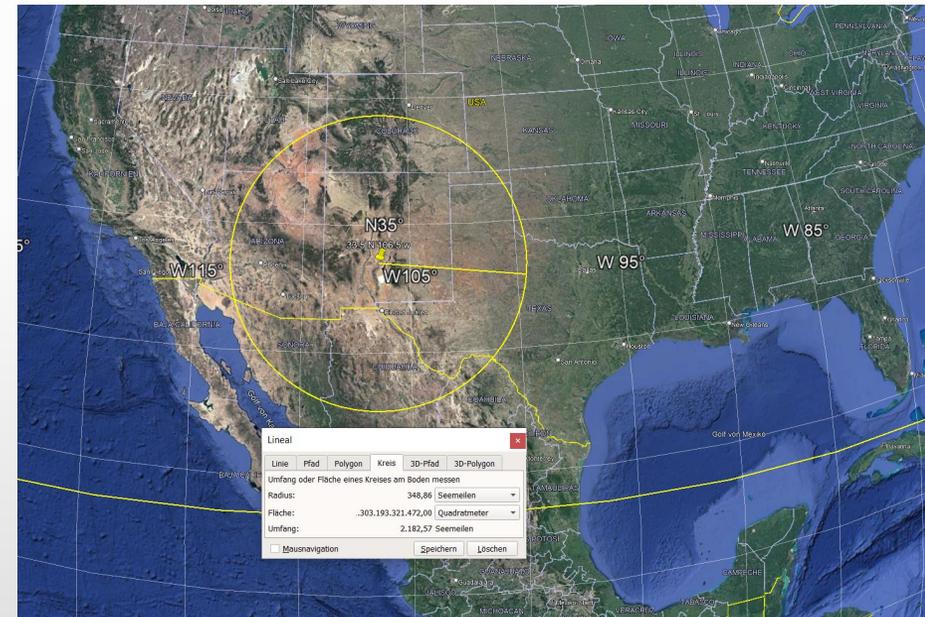


Jamming and Spoofing

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 JAMMING/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.

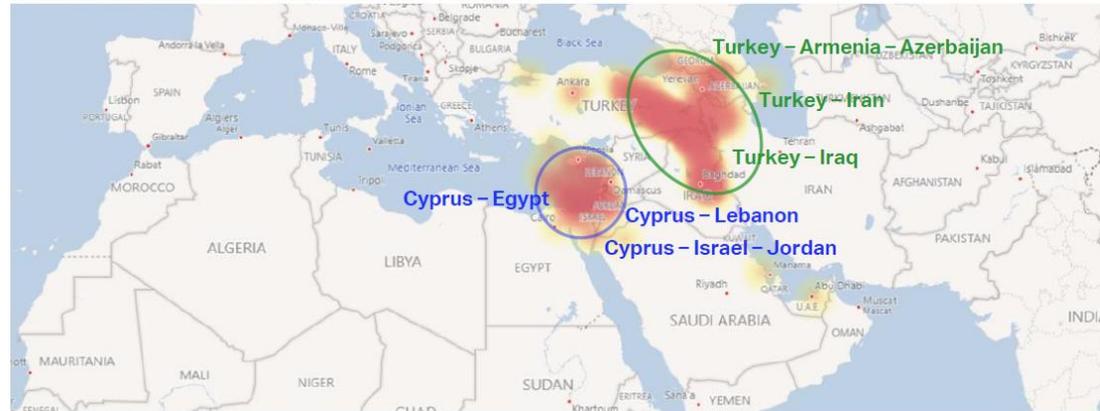
3-PILOTS ARE EXPECTED TO INFORM THE RELEVANT ATS UNIT IN THE EVENT OF GPS SIGNAL OUTAGE IN ORDER TO REPORT IT TO THE CONCERNED AUTHORITIES AND TAKE THE APPROPRIATE ACTION TO ENSURE THAT ALL FLIGHT OPERATIONS ARE CARRIED IN SAFE AND EFFICIENT MANNER. 05 AUG 00:00 2023 UNTIL 04 NOV 23:59 2023. CREATED: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

Reported waypoints or coordinates of GNSS/GPS interference

One report may report GNSS/GPS interference across multiple area.



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.



Phase of Flight: ALL	Applicable CNS: Navigation, Surveillance
Version: 3.0.0	Date: 30 March 2023

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.



POSITION PAPER

21POS07
6 October 2021

IFALPA has continuously voiced concern and alarm about GPS / GNSS interference and effects on safety since many years !

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/3307/19sab04-loss-of-gps-signal-at-guanajuato-international-airport-mmlo.pdf>
- <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;
- https://alpajapan.org/cms_202306/wp-content/uploads/19sab07-gnss-vulnerabilities.pdf



Latest twist: not just jamming, but SPOOFING is observed. Aircraft navigation- and safety net systems are disrupted.



SAFETY BULLETIN

23SAB08

17 October 2023

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.

3

ORZZ
Iraq

OPSGROUP member report of GPS spoofing over Iraq airspace. Event started in the northern region of Erbil. Crew lost navigational integrity over nearly the entire crossing of the ORBB/Baghdad FIR due to enroute high altitude GPS spoofing (falsified position, not jammed as usual). Aircraft then entered full degrade. GPS was 60NM offset, the IRS were considered unreliable. Crews observed 3 or more aircraft affected. ATC was unaware according to crew. Situation was resolved by receiving radar vectors by ATC to fly along the airway. More info at [Safeairspace](#).





KATE ZIMMERMAN

Chief data scientist at Virginia-based HawkEye 360, which flies 18 satellites in three-satellite clusters to pinpoint radio signals emanating from radars, GPS jammers and communications devices.



This illustration represents the variety of signals that HawkEye 360's radio frequency satellites detect, with blue representing the Automatic Identification System signals transmitted by ships.

HawkEye 360

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



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