GNSS integrity

Challenges with Jamming & Spoofing in Civil Aviation
Main Focus on Flight Test Instrumentation

COMMERCIAL AIRCRAFT

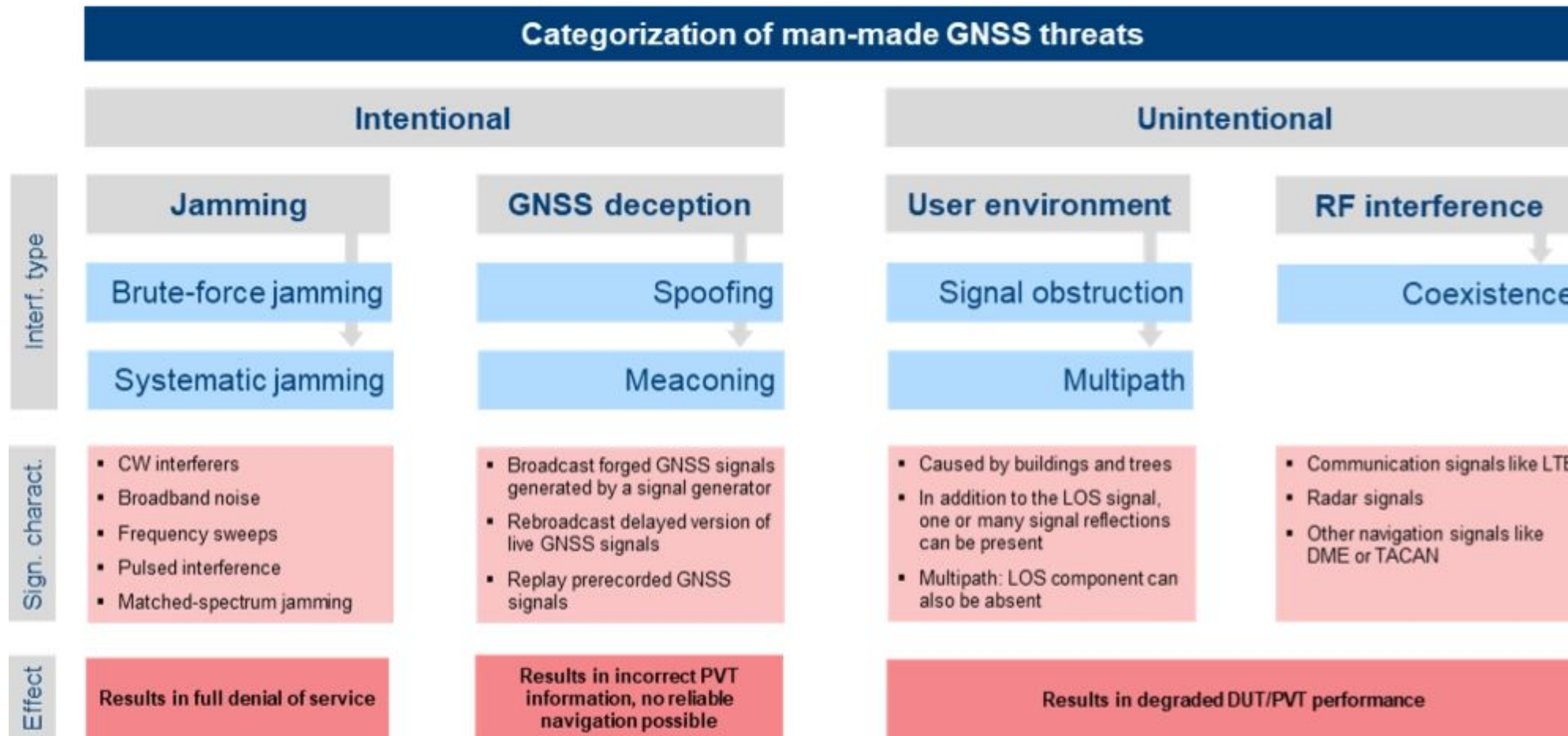Fabrice LAPEYRADE - October 2025

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Agenda

– Jamming and Spoofing definitions

– Aviation status

– Jamming/Spoofing dashboards

– Inertial-hybrid architecture

  – Avionics & Instrumentation (FTI)

– Jamming/Spoofing detection algorithms

– OSNMA

– CRPA antennas

– JammerTest event

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Jamming and Spoofing definitions

In the past decades, most of GNSS threats in the real world were unintentional and/or limited in range!

Categorization of man-made GNSS threats

	Intentional		Unintentional	
	Jamming	**GNSS deception**	**User environment**	**RF interference**
Interf. type	Brute-force jamming	Spoofing	Signal obstruction	Coexistence
	Systematic jamming	Meaconing	Multipath	
Sign. charact.	• CW interferers • Broadband noise • Frequency sweeps • Pulsed interference • Matched-spectrum jamming	• Broadcast forged GNSS signals generated by a signal generator • Rebroadcast delayed version of live GNSS signals • Replay prerecorded GNSS signals	• Caused by buildings and trees • In addition to the LOS signal, one or many signal reflections can be present • Multipath: LOS component can also be absent	• Communication signals like LTE • Radar signals • Other navigation signals like DME or TACAN
Effect	Results in full denial of service	Results in incorrect PVT information, no reliable navigation possible	Results in degraded DUT/PVT performance	

Credits: Testing GNSS receivers against jamming and spoofing attacks - GPS World

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Aviation status

Many areas are impacted and threats/zones **are evolving and growing over the time**:
Global Navigation Satellite System (GNSS) Outages and Alterations | EASA -
https://www.easa.europa.eu/en/domains/air-operations/global-navigation-satellite-system-outages-and-alterations

FIRs affected by jamming and spoofing

Although GNSS jamming and spoofing can be encountered anywhere in the world, according to the data collected so far, the
mainly affected FIRs to date are the following:

powered by **Data4Safety**

impacted FIRs in the last 7 days on 01/10/2025

src: ads-b data and reports

rank	reg...	ICAO	name	spoofing	reported
1	EUR	LTAA	ANKARA	*	
2	EUR	EPWW	WARSZAWA	*	
3	MID	ORBB	BAGHDAD	*	
4	ASIA	VYYF	YANGON	*	
5	EUR	ESAA	SWEDEN	*	
6	EUR	LBSR	SOFIA	*	

impacted FIRs in the last 30 days on 01/10/2025

src: ads-b data and reports

rank	reg...	ICAO	name	spoofing	reported
1	EUR	LTAA	ANKARA	*	
2	EUR	EPWW	WARSZAWA	*	
3	MID	ORBB	BAGHDAD	*	
4	ASIA	VYYF	YANGON	*	
5	EUR	ESAA	SWEDEN	*	
6	EUR	UUWV	MOSCOW	*	

Extract/overview of long lists…

FIRs in EUR region   FIRs not in EUR region

FIR: Flight Information Region

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Jamming dashboard - principle & FlightRadar24

Several dashboards available that reflects Jamming information
- based on GNSS integrity indexes found in ADS-B (transponders) data from aircrafts overflying these areas
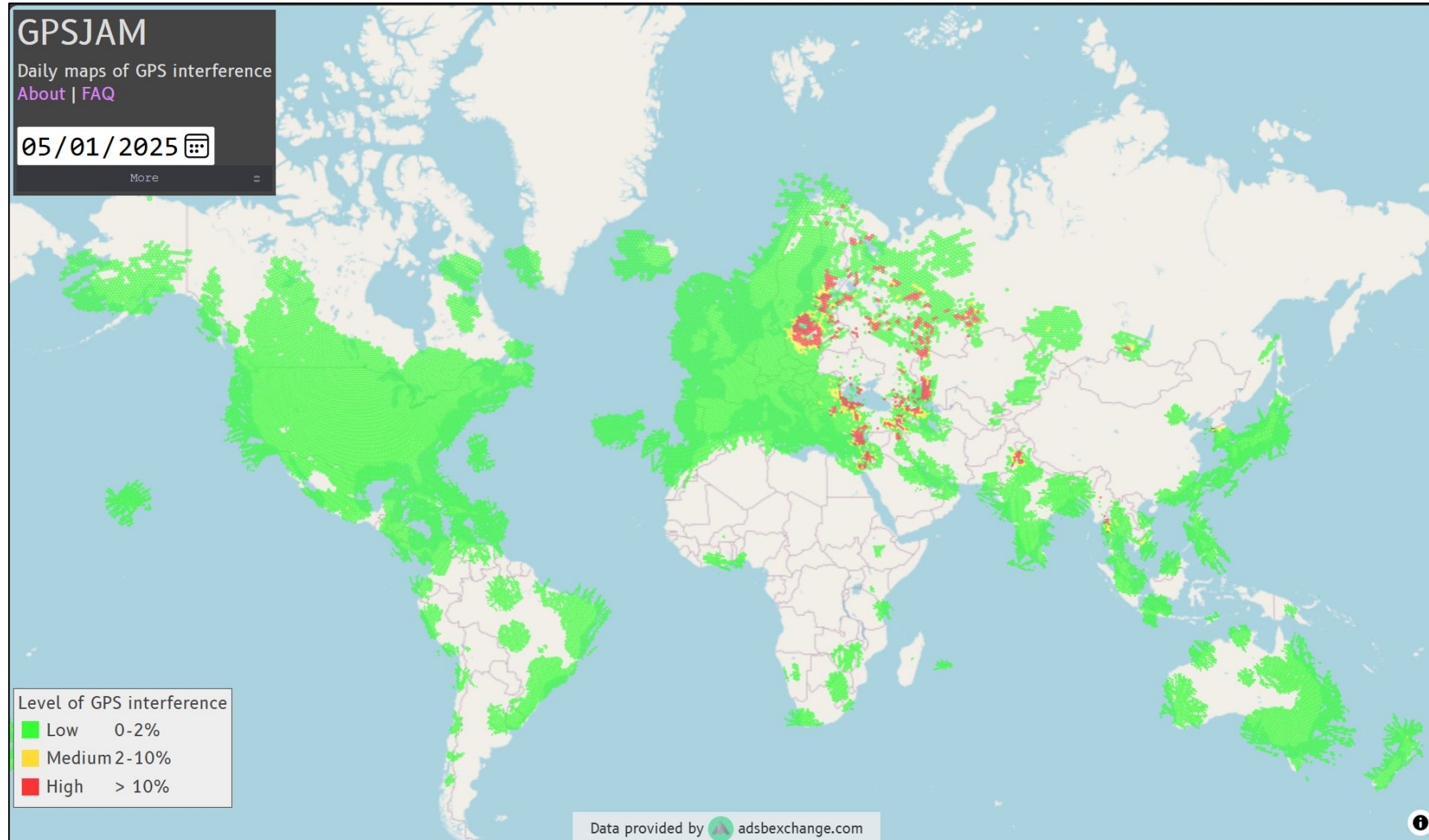
Examples:

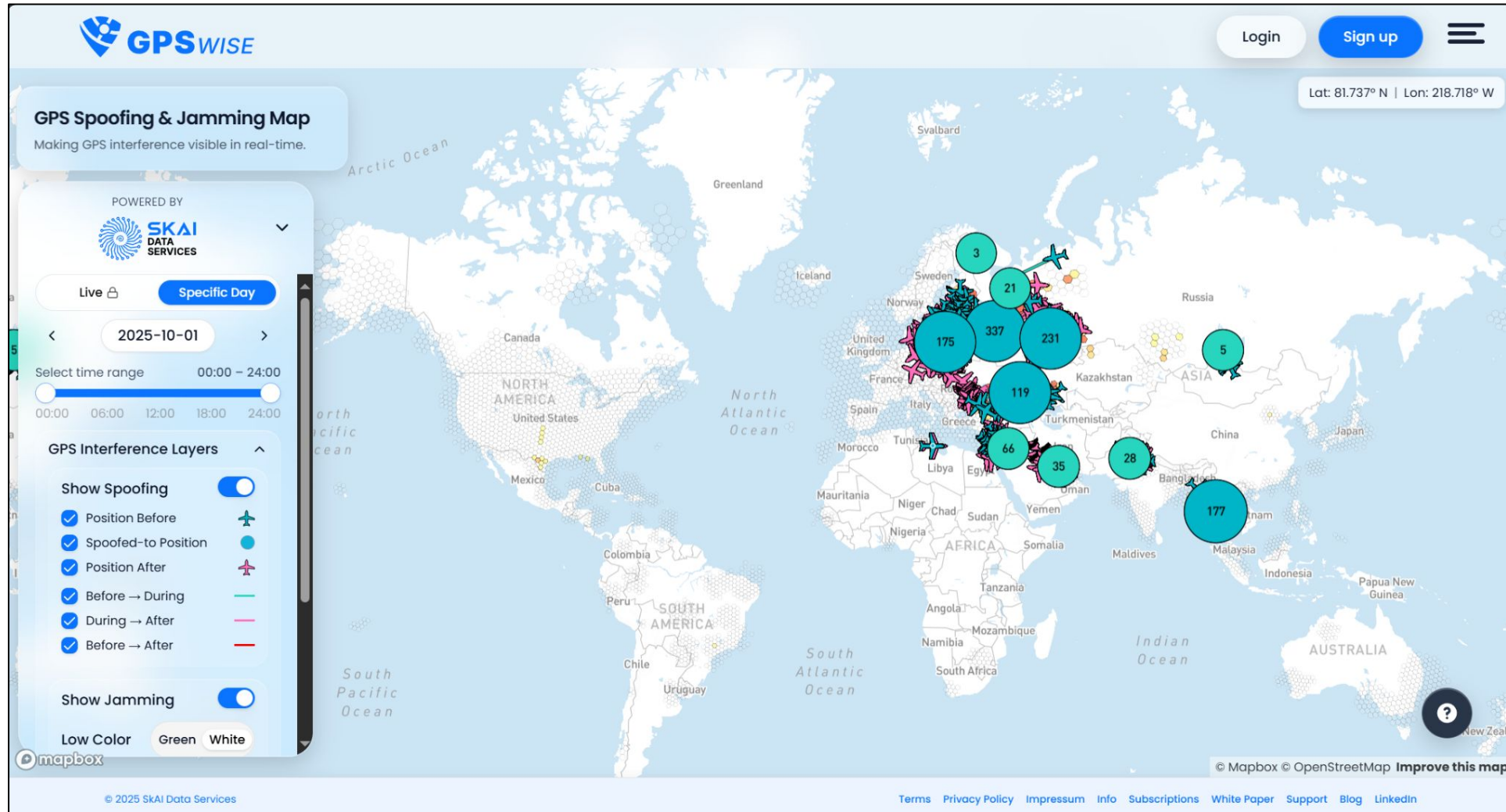GPS jamming & interference map | Flightradar24 - https://www.flightradar24.com/data/gps-jamming
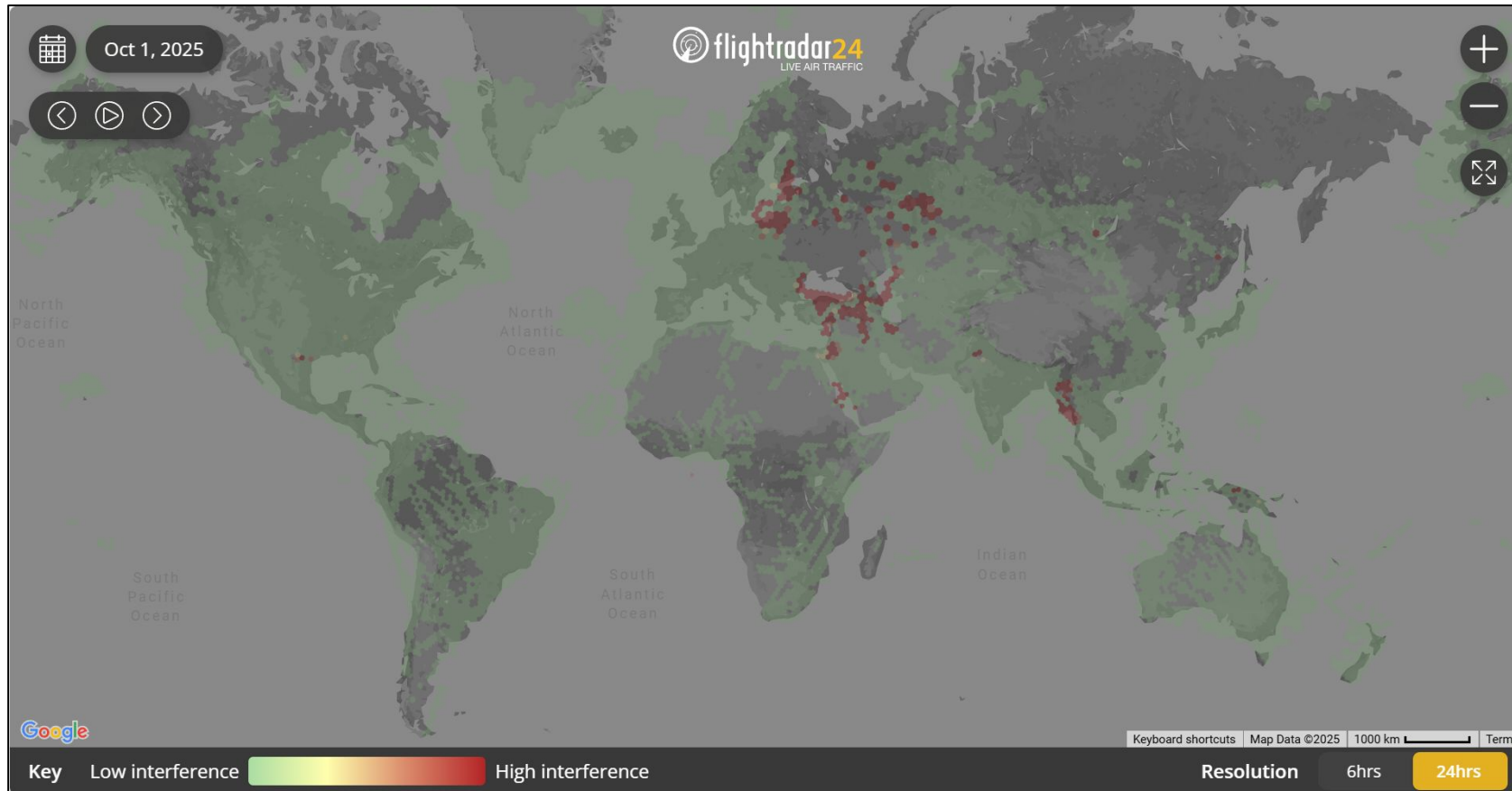
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Jamming dashboard - GPSjam.org

http://GPSjam.org

Jamming dashboard - GPS wise

GPSwise | Live GPS Spoofing & Jamming Map - https://gpswise.aero/

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Jamming dashboard - Stanford university

GNSS Interference Detection using ADS-B - https://waas-nas.stanford.edu/#/heatmap/

Jamming dashboard - Airbus SkyWise

Airbus is also carefully monitoring the situation in direct link with our **customers** and all aviation stakeholders, including airworthiness authorities (like EASA)
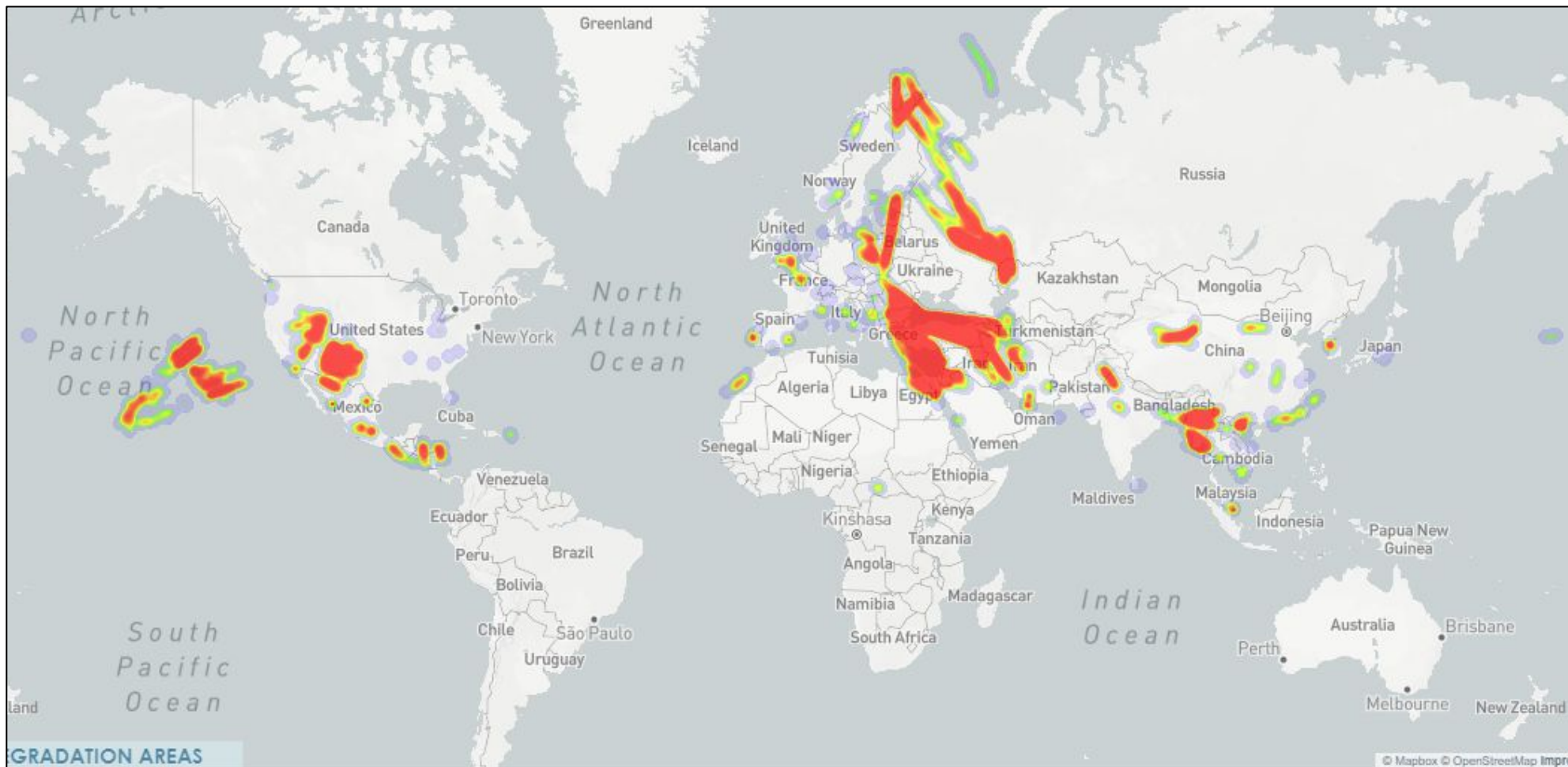
Credits: Timo Warns (Airbus) - ITSNT 2024

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Inertial-hybrid architecture - Airbus avionics in "serial" aircrafts

- GNSS is used for Navigation (NAV), but also for Surveillance (SURV) and Communication (COM) functions
- Navigation (NAV) position outputs rely mostly on **Inertial Reference System (IRS)**:
  1. IRS *tightly-coupled* hybrid with GNSS
  2. If GNSS lost then NAVAIDS & IRS
     - NAVAIDS: DME/DME or DME/VOR
  3. If NAVAIDs lost then IRS-only
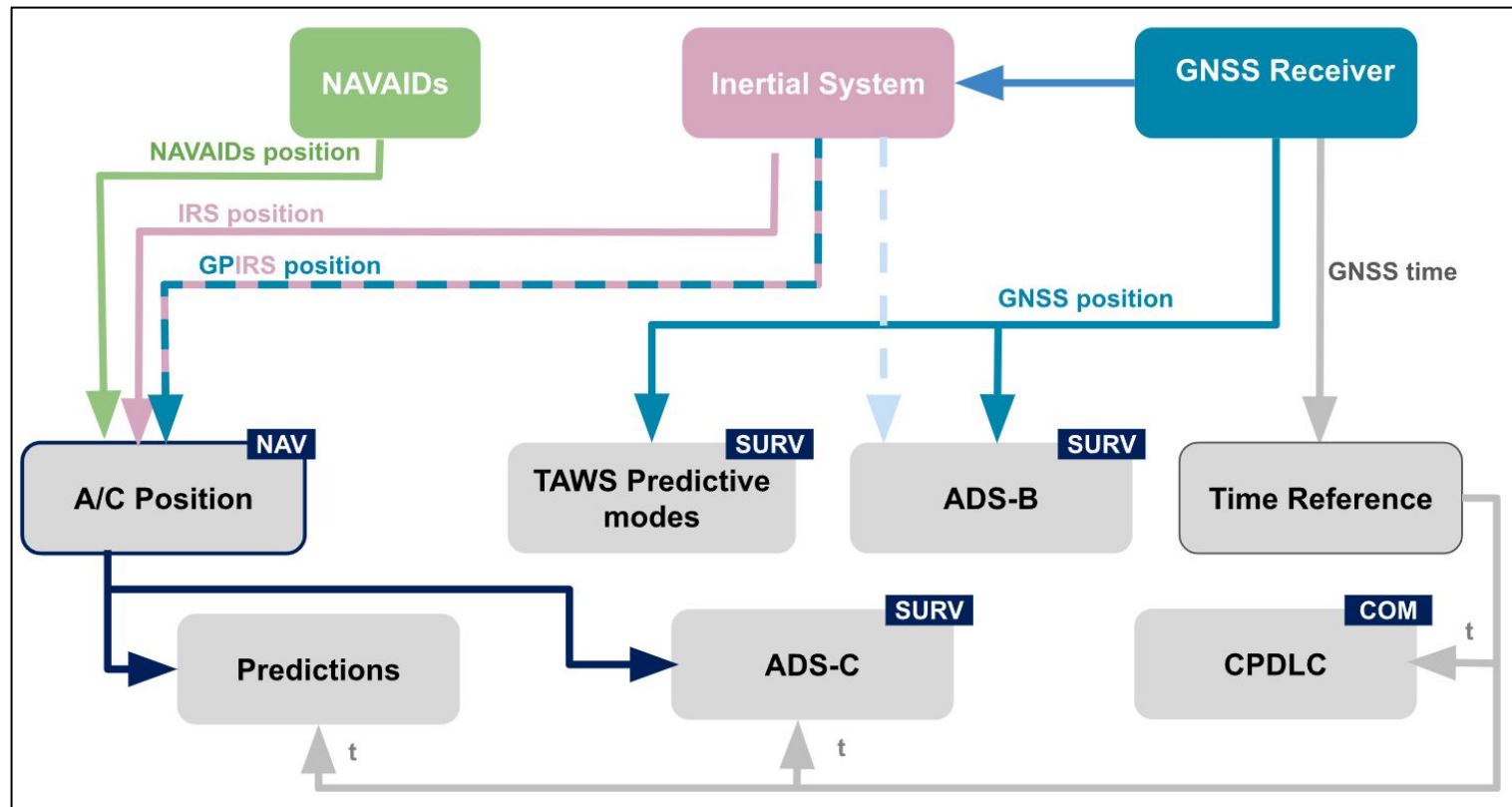
Acronyms:
A/C: Aircraft
ADS-B: Automatic Dependent Surveillance-Broadcast
ADS-C: Automatic Dependent Surveillance-Contract
CPDLC: Controller-Pilot Data Link Communication
DME: Distance Measuring Equipment
GPIRS: GPS and IRS hybridized computation
IRS: Inertial Reference System
NAVAIDs: Navigation Aids
TAWS: Terrain Awareness Warning System
VOR: Very High Frequency (VHF) Omnidirectional Ranging

Credits: Timo Warns (Airbus) - ITSNT 2024

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Inertial-hybrid architecture - Flight Test Instrumentation (FTI)
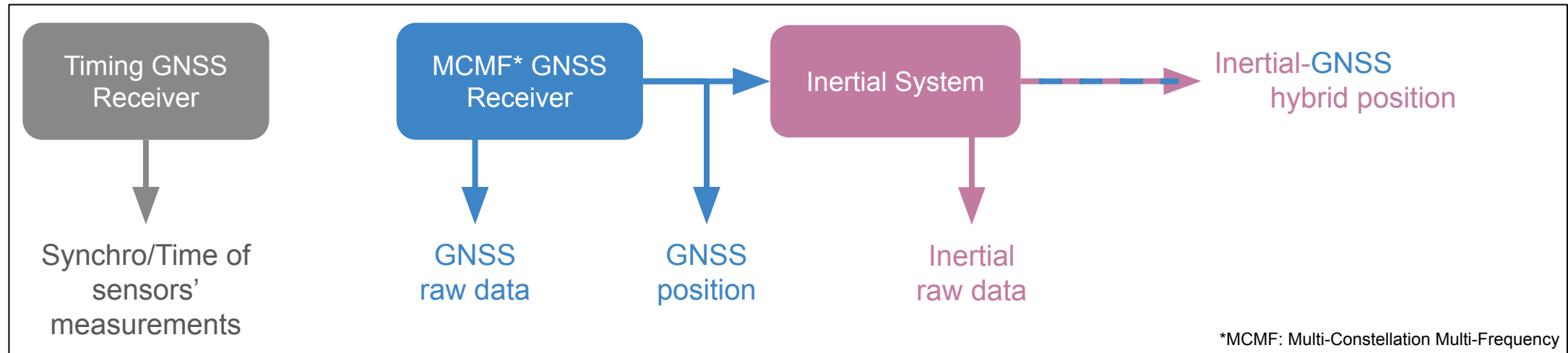
- GNSS used for both Time synchronization and high-accuracy Reference Trajectory measurements
- Position output available in a ***loosely-coupled*** hybrid between GNSS and Inertial system (with backward INS error correction)
    - Kalman filters designed to **detect outliers** by comparing 3D modelling inconsistencies between INS and GNSS
    - Originally created to filter out spurious results from multipath effects
    - Avoids using spoofed values as well
    - In case of outlier, standard deviations are growing accordingly to reflect related accuracy statistics
- ➔ **Need to detect Jamming & Spoofing and mitigate also at upper stages (GNSS receiver and/or antenna)**

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Airbus Amber

Jamming & Spoofing - FTI detection & mitigation

Solutions used for FTI for GNSS jamming/spoofing detection (and mitigation):

- Lack of open platforms for such algorithms

- Many useable from proprietary GNSS manufacturers' algorithms

*Embedded in receivers such as: (non-exhaustive excerpt)*

- Septentrio AIM+

- Javad

- Trimble RTX NMA

Spoofing detected!
OSNMA is at work

Spoofing attack

Satellites - Tracked: 18 / Used: 12 | GPS - 2/0 | GLO - 6/5 | GAL - 3/2 | BDS - 7/5 | QZSS - 0/0 | NavIC - 0/0 | SBAS - 0/0 | LBAND - 0/0 | GLCDMA - 0/0

Spoofed   Jammed   Spoofed and Jammed
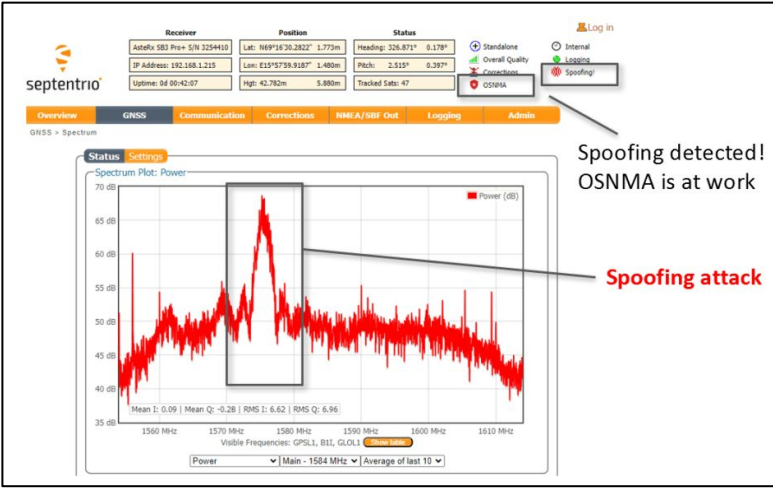
Satellites - Tracking Information

| | ALL | GPS | GLONASS | Galileo | BeiDou | QZSS | NavIC | SBAS | MSS |

SV	Type	Elev. [°]	Azim. [°]	L1-C/No [dBHz]	L1	NMA	L2-C/No [dBHz]	L2	L5-C/No [dBHz]	L5	IODE	URA [m]	Type
5	GPS	75.80	149.90	48.1	CA	Authenticated		+CL	-	-	52	2	IIR-M
9	GPS	-45.00	0.00	-	CA	?	-	E/CM+CL	-	I+Q	-	-	IIF

|	QZSS	NavIC		SBAS		MSS	
	NMA	E5-C/No [dBHz]	E5	IODE	URA [m]		
		51.5	Alt	39	3.12		
4	Galileo	14.85	64.25	37.4	CBOC	Authenticated	33	3.12
6	Galileo	17.71	89.73	38.6	CBOC	44.3	Alt	39	3.12

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Galileo OSNMA tests

Galileo Open Service Navigation Message Authentication (OSNMA)
https://www.gsc-europa.eu/galileo/services/galileo-open-service-navigation-message-authentication-osnma

Fully operational since July 2025!

Used by Airbus in Flight Tests during JammerTest 2025:

- through COTS (Septentrio mosaic-x5) GNSS receiver as part of FTI

  → JammerTest OSNMA results to be analysed
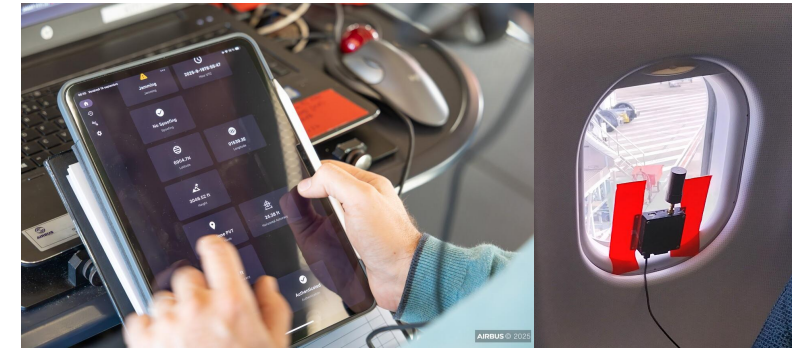
Interface on crew's EFB

COTS OSNMA
receiver & antenna

Another long-term mitigation: Authenticated SBAS

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J&S Mitigation: CRPA technology for FTI

Use of Controlled Reception Pattern Antennas (CRPA) helps such J&S mitigation

Example of **Calian CR8894SXF+**

• Dual band GNSS L1/L2 signal support

• Supports eXtended Filtering+ (XF+) providing sharp out-of-band signal rejection

• Up to 20-40 dB null depth

• Serial interface provides state information and estimated jammer direction

• IP69K water proof housing

• <u>Single RF feed/output</u> - Compatible with standard GNSS receivers

• Very low power consumption (140 mA)

• Small, lightweight, and low-profile form factor makes it ideal for many uses

• Supports situational awareness, indicates CRPA state: jamming observed/mitigated, frequency, and direction

Used by Airbus in Flight Tests during JammerTest 2025:

  → JammerTest Calian CRPA results to be analysed

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JammerTest 2025 - Airbus experiments

What is JammerTest event?

Intentional Jamming & Spoofing testings organized in Norway by TestNor (private company) liaising with local authorities

Various defined J&S scenarios broadcasted with a dedicated schedule in real environment

One Airbus development flight test aircraft participated to this 2025 edition.

Technologies exposed/tested during this flight test campaign:

- Various avionics computers (from Navigation but not only)
    - with several hardware & software standards/versions
- Galileo OSNMA based on COTS receiver
- CRPA 4 parts GNSS L1/L2 antenna from Calian, used for FTI
- GNSS RF L1& L5 IQ data recorded

Data analysis in progress, expected in coming months

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Thank you

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