Supporting European Aviation

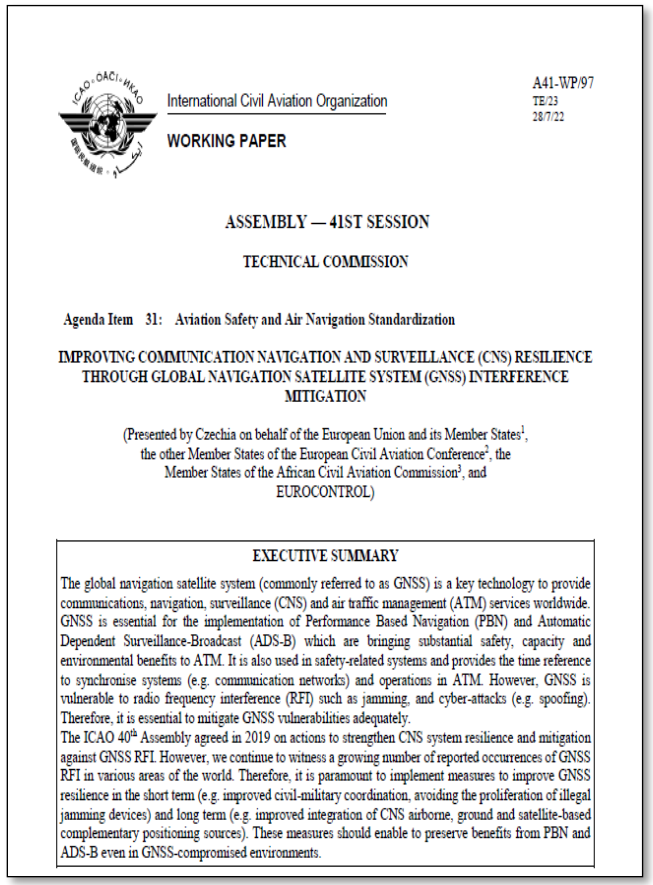
EUROCONTROL

Use of ADS-B for GNSS RFI Monitoring

IDM WS

Hamdi NASSER, EUROCONTROL
hamdi.nasser@eurocontrol.int
06/12/2022

GNSS RFI: a global problem



International Civil Aviation Organization

WORKING PAPER

A41-WP/97
TE/23
28/7/22

ASSEMBLY — 41ST SESSION

TECHNICAL COMMISSION

Agenda Item 31: Aviation Safety and Air Navigation Standardization

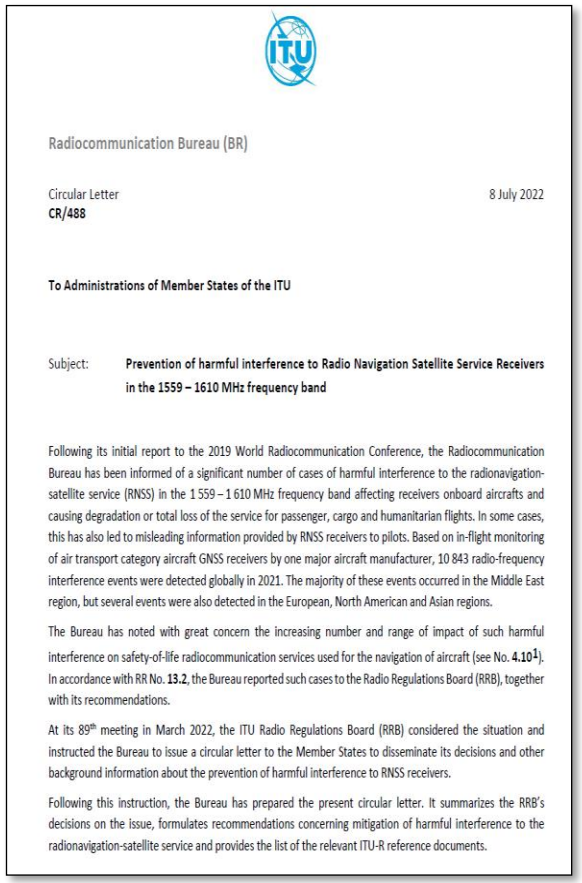
IMPROVING COMMUNICATION NAVIGATION AND SURVEILLANCE (CNS) RESILIENCE THROUGH GLOBAL NAVIGATION SATELLITE SYSTEM (GNSS) INTERFERENCE MITIGATION

(Presented by Czechia on behalf of the European Union and its Member States[1], the other Member States of the European Civil Aviation Conference[2], the Member States of the African Civil Aviation Commission[3], and EUROCONTROL)

EXECUTIVE SUMMARY

The global navigation satellite system (commonly referred to as GNSS) is a key technology to provide communications, navigation, surveillance (CNS) and air traffic management (ATM) services worldwide. GNSS is essential for the implementation of Performance Based Navigation (PBN) and Automatic Dependent Surveillance-Broadcast (ADS-B) which are bringing substantial safety, capacity and environmental benefits to ATM. It is also used in safety-related systems and provides the time reference to synchronise systems (e.g. communication networks) and operations in ATM. However, GNSS is vulnerable to radio frequency interference (RFI) such as jamming, and cyber-attacks (e.g. spoofing). Therefore, it is essential to mitigate GNSS vulnerabilities adequately.

The ICAO 40th Assembly agreed in 2019 on actions to strengthen CNS system resilience and mitigation against GNSS RFI. However, we continue to witness a growing number of reported occurrences of GNSS RFI in various areas of the world. Therefore, it is paramount to implement measures to improve GNSS resilience in the short term (e.g. improved civil-military coordination, avoiding the proliferation of illegal jamming devices) and long term (e.g. improved integration of CNS airborne, ground and satellite-based complementary positioning sources). These measures should enable to preserve benefits from PBN and ADS-B even in GNSS-compromised environments.



Radiocommunication Bureau (BR)

Circular Letter
CR/488

8 July 2022

To Administrations of Member States of the ITU

Subject: **Prevention of harmful interference to Radio Navigation Satellite Service Receivers in the 1559 – 1610 MHz frequency band**

Following its initial report to the 2019 World Radiocommunication Conference, the Radiocommunication Bureau has been informed of a significant number of cases of harmful interference to the radionavigation-satellite service (RNSS) in the 1 559 – 1 610 MHz frequency band affecting receivers onboard aircrafts and causing degradation or total loss of the service for passenger, cargo and humanitarian flights. In some cases, this has also led to misleading information provided by RNSS receivers to pilots. Based on in-flight monitoring of air transport category aircraft GNSS receivers by one major aircraft manufacturer, 10 843 radio-frequency interference events were detected globally in 2021. The majority of these events occurred in the Middle East region, but several events were also detected in the European, North American and Asian regions.

The Bureau has noted with great concern the increasing number and range of impact of such harmful interference on safety-of-life radiocommunication services used for the navigation of aircraft (see No. **4.10**[1]). In accordance with RR No. **13.2**, the Bureau reported such cases to the Radio Regulations Board (RRB), together with its recommendations.

At its 89th meeting in March 2022, the ITU Radio Regulations Board (RRB) considered the situation and instructed the Bureau to issue a circular letter to the Member States to disseminate its decisions and other background information about the prevention of harmful interference to RNSS receivers.

Following this instruction, the Bureau has prepared the present circular letter. It summarizes the RRB's decisions on the issue, formulates recommendations concerning mitigation of harmful interference to the radionavigation-satellite service and provides the list of the relevant ITU-R reference documents.

EASA SIB No.: 2022-02

EASA
European Union Aviation Safety Agency

Safety Information Bulletin
Operations – ATM/ANS
SIB No.: 2022-02
Issued: 17 March 2022

Subject: Global Navigation Satellite System Outage Leading to Navigation / Surveillance Degradation

Ref. Publications:
None.

Applicability:
National Aviation Authorities (NAAs), Air Navigation Service Providers (ANSPs) and air operators.

Description:
In the current context of the Russian invasion of Ukraine, the issue of Global Navigation Satellite Systems (GNSS) jamming and/or possible spoofing has intensified in geographical areas surrounding the conflict zone and other areas.

Eurocontrol, Network of Analysts and open-source data reports analysed by EASA indicate that since 24 February 2022, there are four key geographical areas where GNSS spoofing and/or jamming has intensified, namely:

- Kaliningrad region, surrounding Baltic sea and neighbouring States;
- Eastern Finland;
- The Black Sea; and
- The Eastern Mediterranean area near Cyprus, Turkey, Lebanon, Syria and Israel, as well as Northern Iraq.

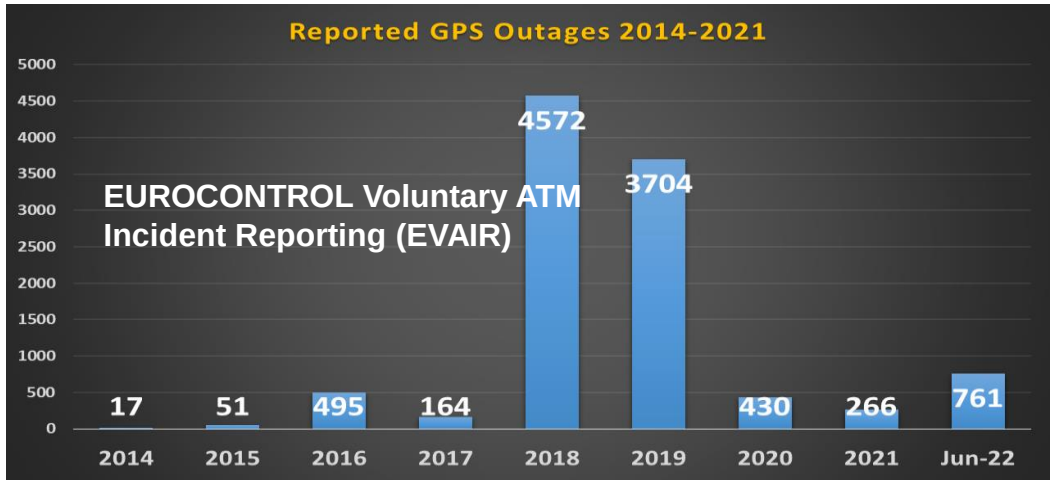
The effects of GNSS jamming and/or possible spoofing were observed by aircraft in various phases of their flights, in certain cases leading to re-routing or even to change the destination due to the inability to perform a safe landing procedure. Under the present conditions, it is not possible to predict GNSS outages and their effects. The magnitude of the issues generated by such outage would depend upon the extent of the area concerned, on the duration and on the phase of flight of the affected aircraft.

- **Ops contingency procedures**
- **Retain essential CNS infrastructure**
- **Monitoring and reporting**
- **Better integration and resilience of airborne systems**
- **Coordination between authorities**
- Legal framework

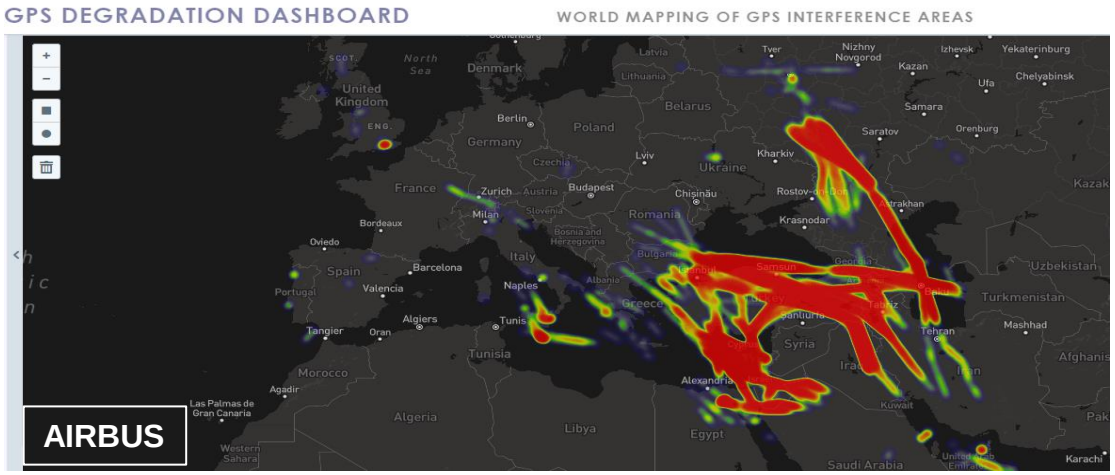
Satellite Interference Reporting and Resolution System
https://www.itu.int/en/ITU-R/space/SIRRS/Pages/default.aspx
Official reports are essential to justify actions

Motivation

- GNSS RFI has become a widespread problem affecting aviation
- GNSS is the primary enabler for PBN and ADS-B applications and is becoming an increasingly essential technology used in various other CNS applications
- Reporting does not reflect real field conditions



2018 / 2019 trend: average of 10 GPS reports DAILY!
2020/2021 decrease due to reduced flights (COVID) and reporting
2022: increase due to the war in Ukraine (main peak in March/April)



2021: 10843 events detected worldwide
RFI continues despite reduced pilot reports

The number of reports gives a small indication but does not reflect the full picture (dependent on the willingness to report)

→ Need for a tool allowing automatic detection and reporting of GNSS RFI

OPS Requirement

- 2014: Preparation for EU PBN Implementing Rule:
  - ATC Human in the Loop Impact Studies for impact assessment including GPS Loss
  - Budapest simulation, high level of “GPS-only for PBN” traffic (20%)
  - ATCO Statement: **“I can deal with GPS RFI, just tell me when it starts, how many sectors are affected, and when it ends”**

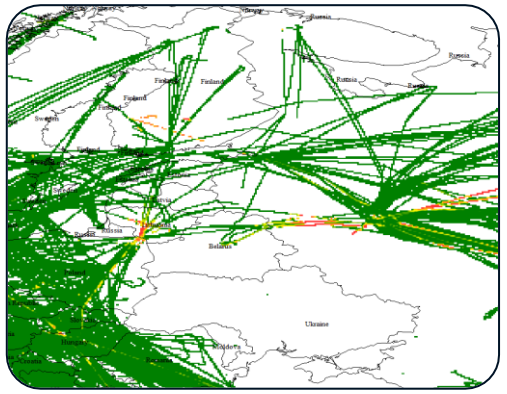
- Validated OPS Requirement through EUROCONTROL NETOPS
  - **NETOPS Conclusion 23/10:** NETOPS agreed the following recommendations:
  - *b)* With reference to paragraph 3.2: *confirm the Operational need to be aware of the **geographic area** of GPS outages and that they (**ATC**) intend to use this information in the context of **contingency operations**.*

Summary Report Twenty-third Meeting (NETOPS/23) Brussels, 28 Feb - 1 March 2019, NETOPS/24 WP02

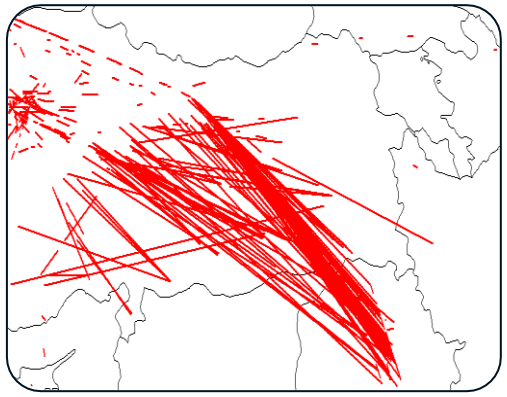
Developing Solutions: ADS-B Monitoring

- Monitoring Objectives
  - **Operational Risk Management**:
    - Detect RFI area and notify airspace users
    - Identify affected flights: depends on other available CNS capabilities and aircraft equipage
    - Prevent a potential ATC/pilot workload increase
  - **Technical Intervention**
    - Determine RFI Source Location if possible
    - Report incident to radio regulator for resolution

Detection criteria of RFI:
- A degraded NIC value reported by several aircraft in the same area
- A good satellite geometry in the concerned area
- Absence of bad space weather conditions in in the concerned area

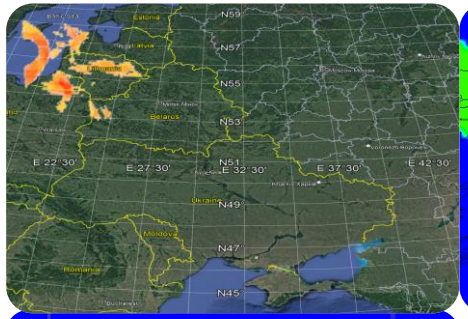


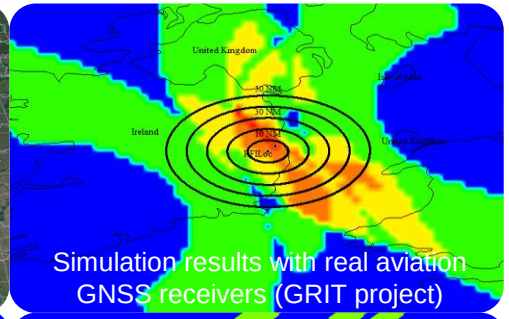
ADS-B NIC



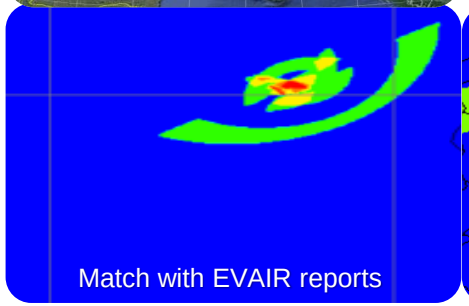
ADS-B missing position reports

Validation of the RFI glocalization capability

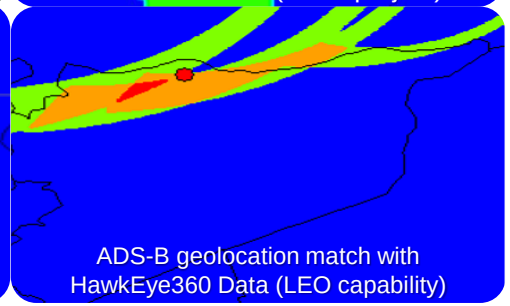




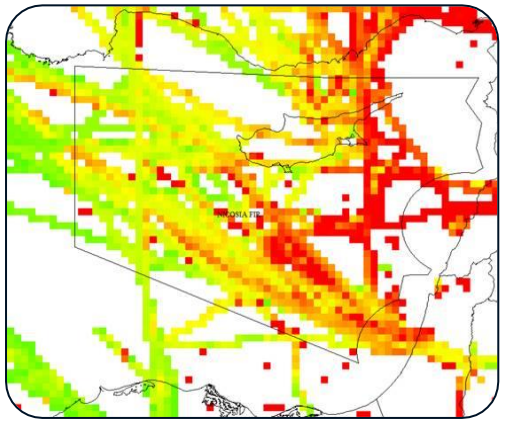
Simulation results with real aviation GNSS receivers (GRIT project)



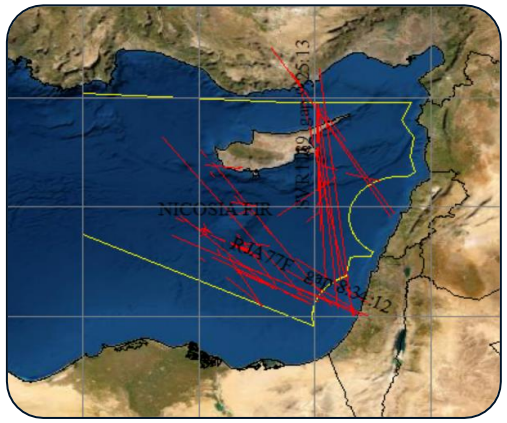
Match with EVAIR reports



ADS-B geolocation match with HawkEye360 Data (LEO capability)

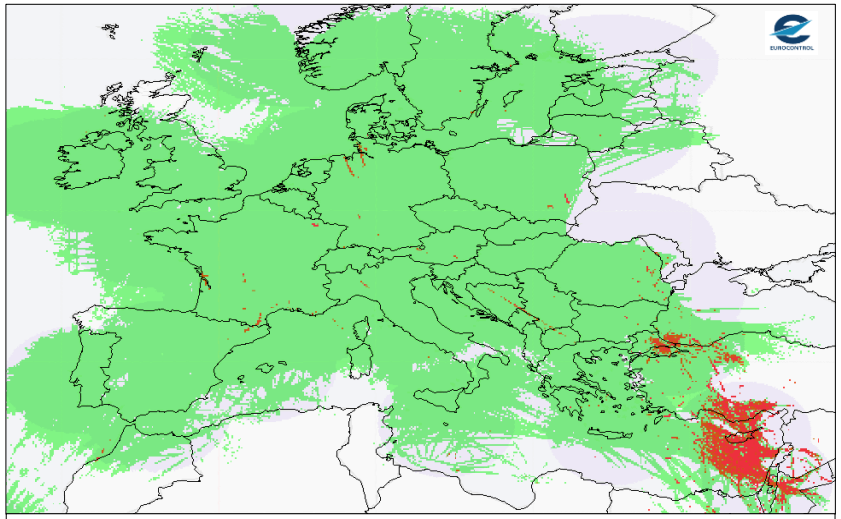


ADS-B PIC

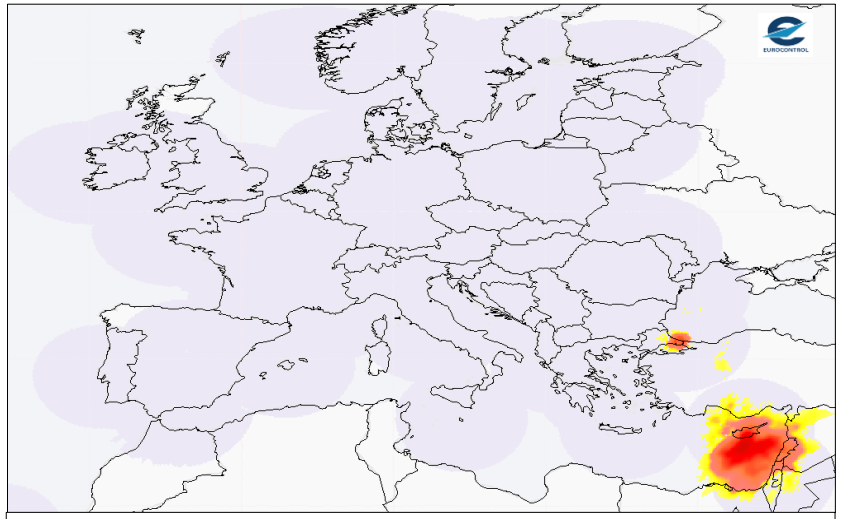


ADS-B missing position reports

Navigation status monitoring (NASM) – IOC and weekly update

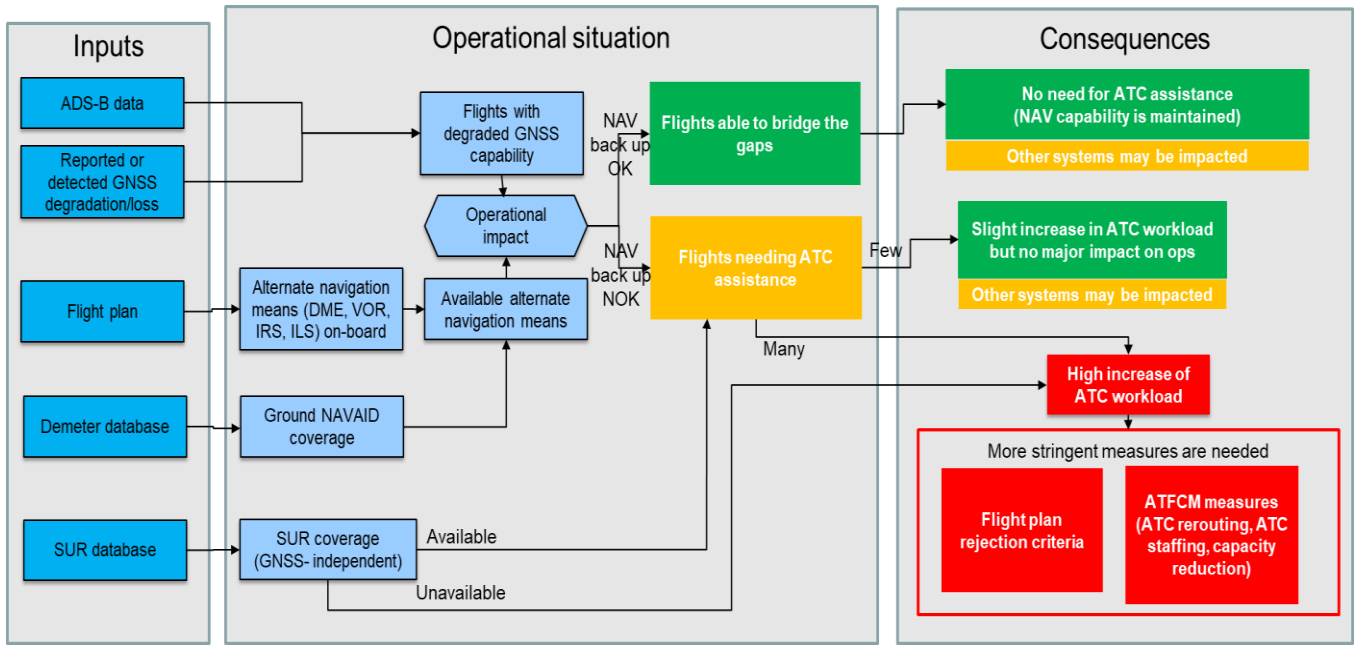


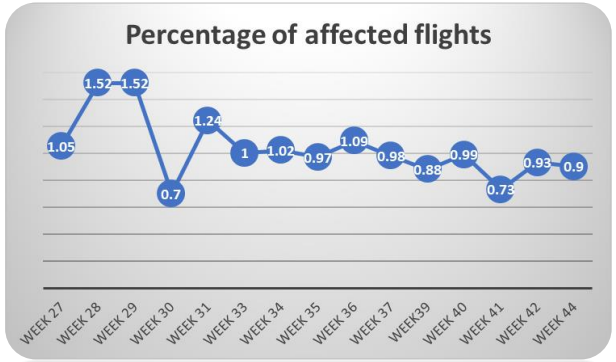
GNSS quality indicators reported through ADS-B



GNSS RFI source location heatmap

Operational impact assessment



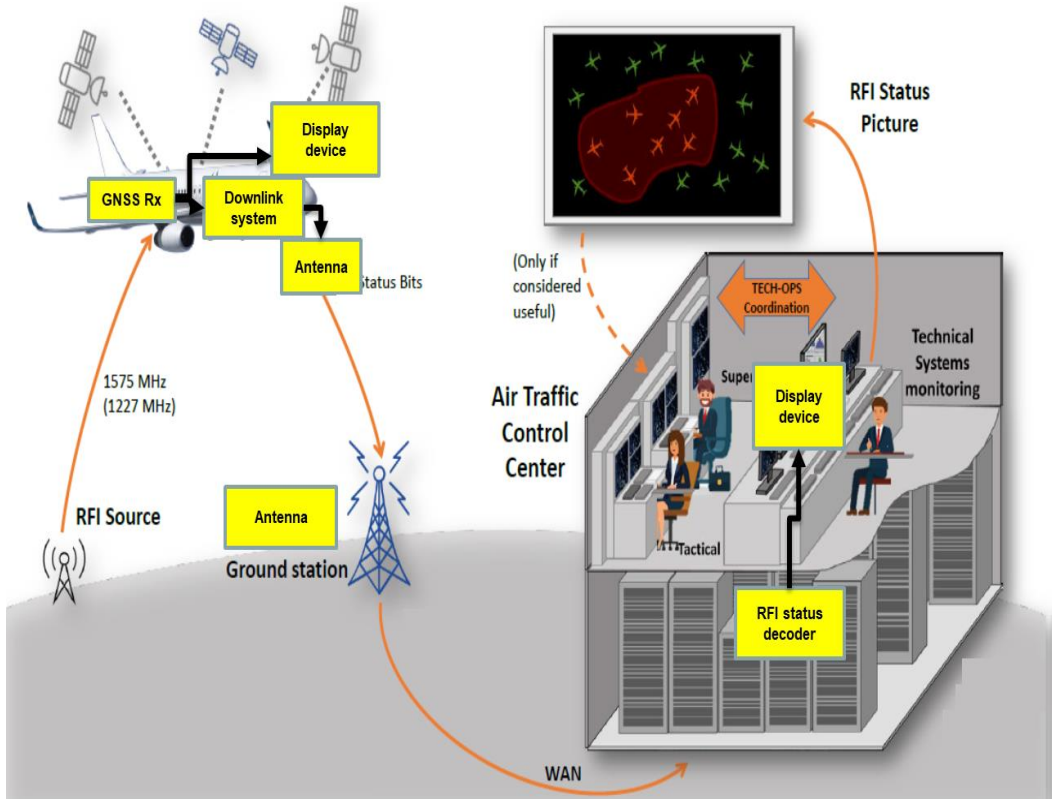


Tactical: **Near real time capability**

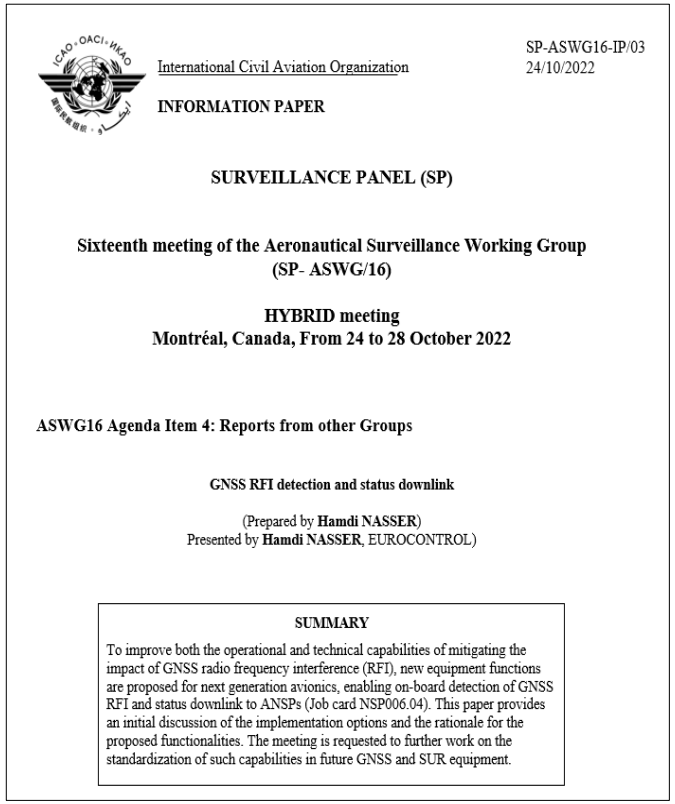
Ensure that there is a timely reaction to a significant event, allowing to identify affected flights, inform all concerned actors and implement appropriate mitigation measures (such as reducing certain traffic through an impacted airspace).

Envisioned Next Generation RFI Mitigation Function

Functional architecture



➔ ***Work in progress***



International Civil Aviation Organization

SP-ASWG16-IP/03
24/10/2022

INFORMATION PAPER

SURVEILLANCE PANEL (SP)

Sixteenth meeting of the Aeronautical Surveillance Working Group (SP- ASWG/16)

HYBRID meeting
Montréal, Canada, From 24 to 28 October 2022

ASWG16 Agenda Item 4: Reports from other Groups

GNSS RFI detection and status downlink

(Prepared by **Hamdi NASSER**)
Presented by **Hamdi NASSER**, EUROCONTROL)

SUMMARY

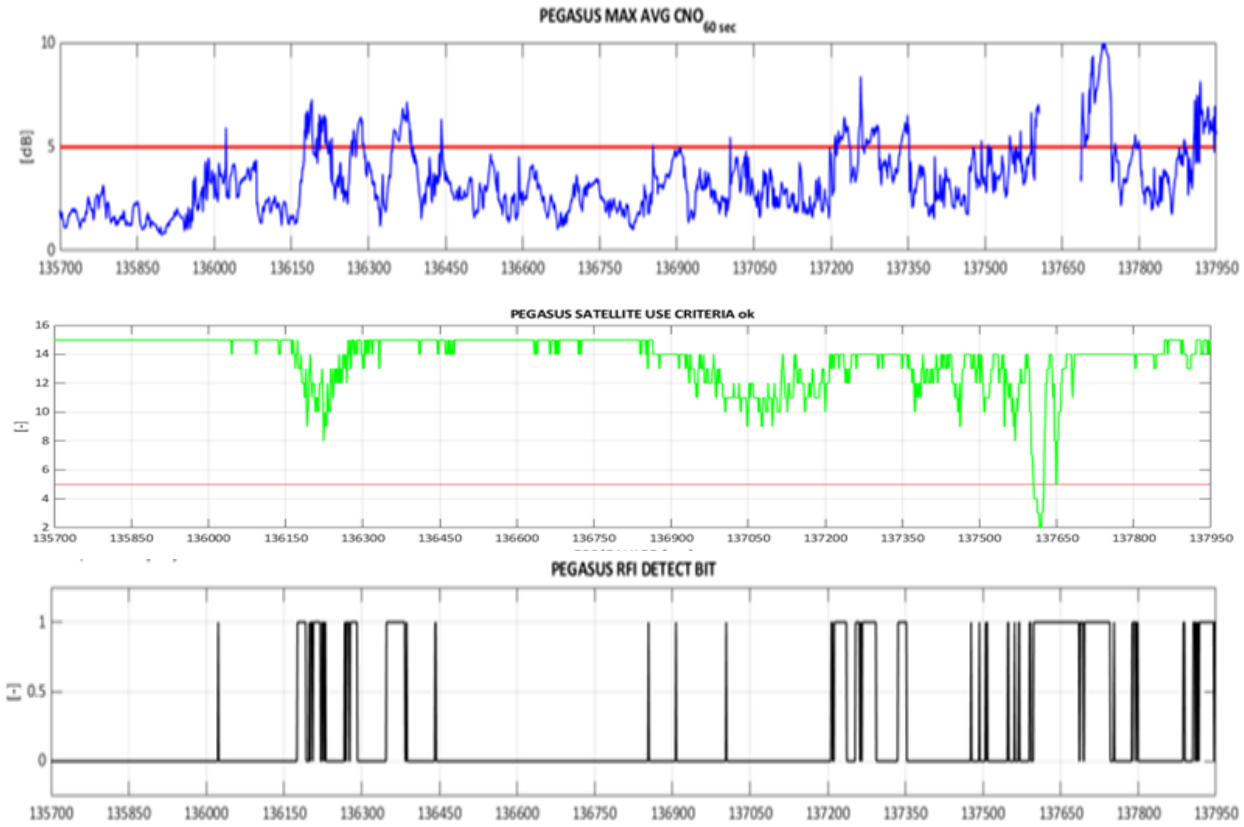
To improve both the operational and technical capabilities of mitigating the impact of GNSS radio frequency interference (RFI), new equipment functions are proposed for next generation avionics, enabling on-board detection of GNSS RFI and status downlink to ANSPs (Job card NSP006.04). This paper provides an initial discussion of the implementation options and the rationale for the proposed functionalities. The meeting is requested to further work on the standardization of such capabilities in future GNSS and SUR equipment.

Standards

- ICAO NSP agreed job card to work on “GNSS RFI detection and status Downlink”
- Concept presented to EUROCAE / RTCA CSC in 2018
- Concept presented to ASWG and supported by the SUR community
- RTCA SC159 / EUROCAE WG62 is working on the inclusion of an RFI detection function in next generation GNSS standards
- ADS-B is the most suitable link due to commonality of interest (use of GNSS)
- Work on going with the SUR community to define the downlink message and the update rate – will be presented to TSG

PEGASUS – EUROCONTROL GNSS data processing tool

- Implementation of the current MOPS RFI draft requirement in PEGASUS



[DMS:XXX] The equipment shall provide an indication of "L1 RFI detected" if any of the following conditions is met:

a) *A variation of at least 5dB of the averaged "standardized" C/N0 absolute value in the last 60 seconds using at least 5 (TBC) L1/E1 signals broadcast by GPS or GAL satellites passing the Satellite Use Criteria defined in Section 3.1.1.6.3; or*

b) *The number of GPS and GAL L1/E1 signals passing the Satellite Use Criteria defined in Section 3.1.1.6.3 is less than or equal to 4*

Equipment class: All

[DMS:XXX] The "L1 RFI detected" indicator shall return to its normal state if any of the following conditions is met:

a) *Equipment power-on until the number of GPS and GAL L1/E1 signals passing the Satellite Use Criteria defined in Section 3.1.1.6.3 is higher than or equal to 5 during 60 seconds or*

b) *All following conditions are met:*

i. *At least 10 (TBC) tracked L1/E1 signals broadcast by GPS or GAL satellites passing the Satellite Use Criteria defined in Section 3.1.1.6.3*

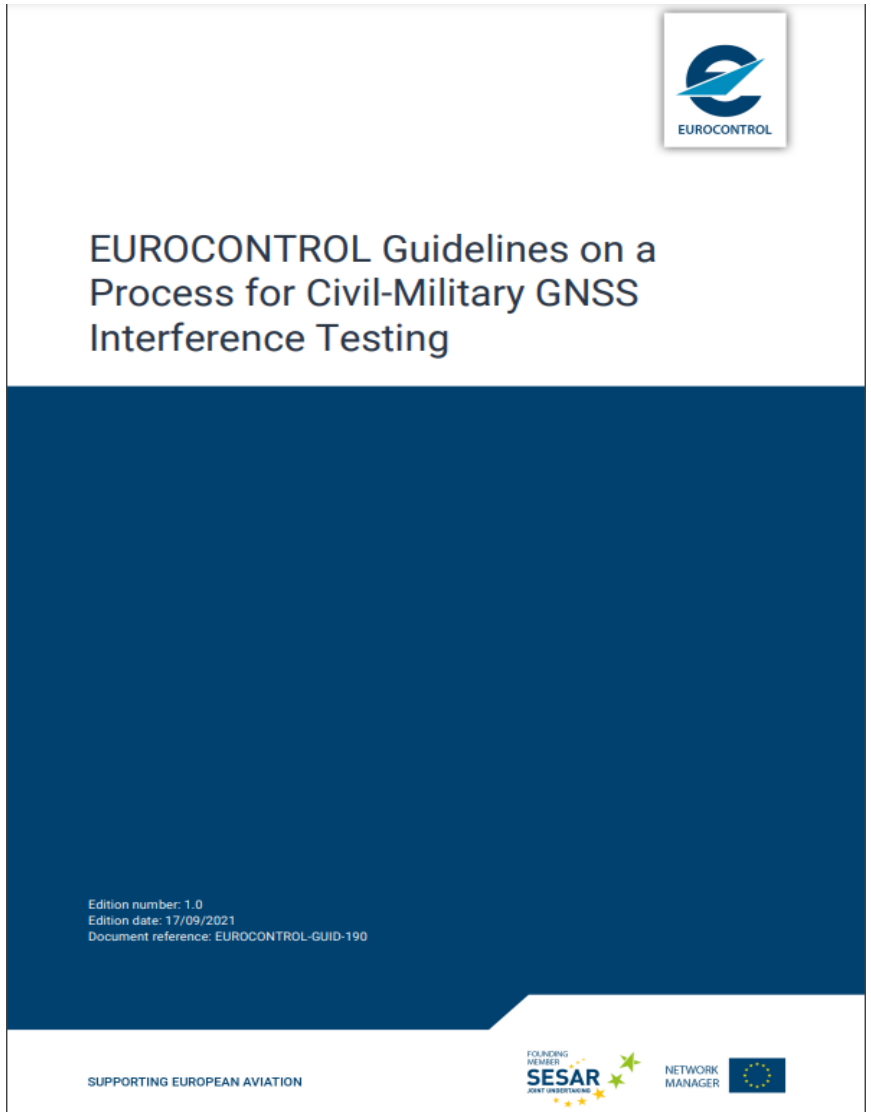
ii. *A variation lower than 5dB of the averaged "standardized" C/N0 absolute value in the last 60 seconds using at least 5 (TBC) L1/E1 signals broadcast by GPS or GAL satellites passing the Satellite Use Criteria defined in Section 3.1.1.6.3.*

Equipment class: All

GRIT project – Aviation Receivers testing and jamming detection

- ION GNSS+ 2022 paper
  - https://www.ion.org/gnss/abstracts.cfm?paperID=11415
- Supporting the definition of DFMC MOPS RFI requirements
- Possible integration in the PEGASUS toolset
  - Flight data analysis
  - RFI detection on ground

EUROCONTROL Guidelines for GNSS Interference Testing



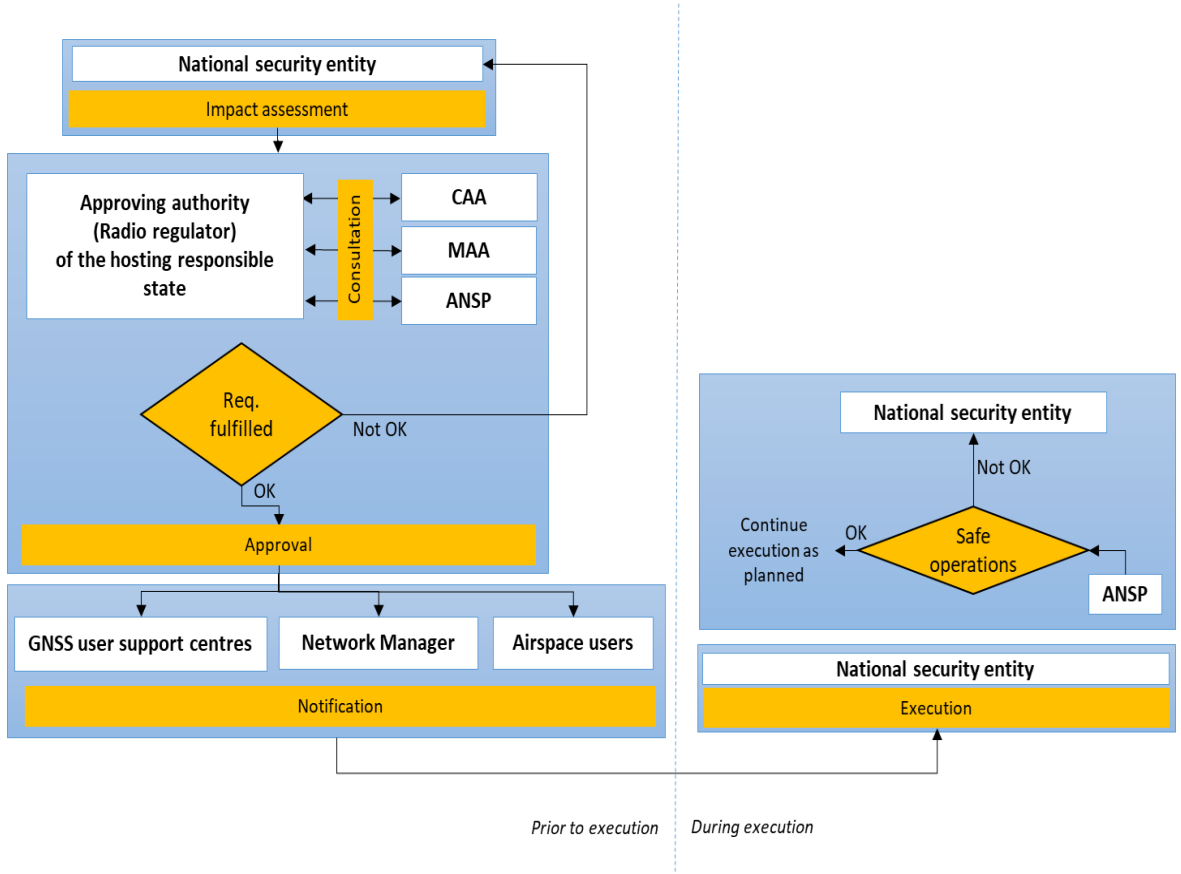
The purpose of this document is to describe a process for the planning, notification and execution of GNSS interference testing

https://www.eurocontrol.int/publication/eurocontrol-guidelines-process-civil-military-gnss-interference-testing

- **GNSS testing planning**
  - Impact assessment
  - Approval process
    - Within national borders testing
    - Cross borders testing
    - High seas testing
  - Testing coordination
- **GNSS testing notification**
  - AIS (NOTAM, AIP SUP, AIC)
  - Notification to NM
  - Notification to other impacted users
- **GNSS testing execution**
  - Airspace users
  - ANSP

- Initial version released in September 2021
- Publication of v2 planned for Q4 2022

EUROCONTROL Guidelines for GNSS Interference Testing



Update finalised:

- Expansion of the scope to include for any state authorized RFI activities
- Review of the impact assessment prior to GNSS interference testing
- Consideration of other notification means (AIP SUP, AIC)
- Consideration of spoofing
- Consideration of danger and restricted areas

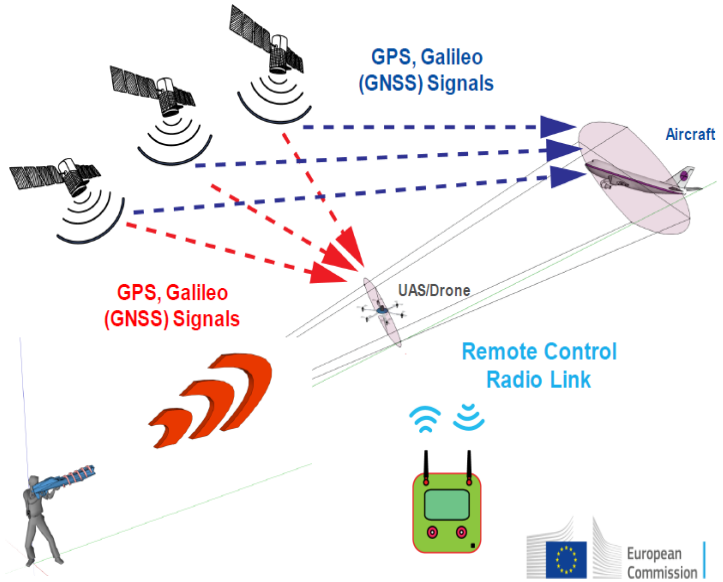
- Reviewed and endorsed by MAB
- Publication of v2 planned for Q4 2022

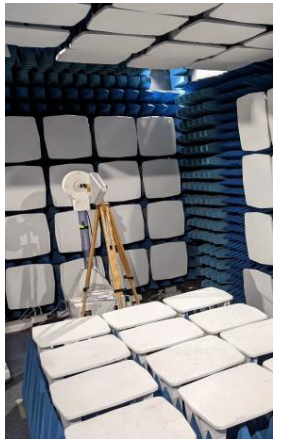
Web-based platform:

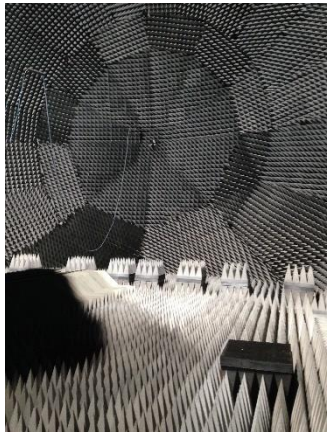
- Calculation of the impacted area / required interference power Graphical display of planned GNSS/RF testing
- Workflow with roles and decisions for users
- Generation of publications proposals (NOTAM and/or AIP SUP)
- Supports the INTERRUPT procedure and nominated PoC

C-UAS

- An **ad hoc group** composed of representatives from EUROCONTROL, EDA, NATO, EC JRC and European police forces/frequency regulators/military
- **Objective**: Determine possible collateral risks to the use of C-UAS jammers
  - i.e. possible risks to non-participating GNSS receivers, including receivers in civil aviation aircraft
  - Risk assessment as a basis for authorizing the safe use of C-UAS
- **Planned activities**: Test plan, Test campaign at JRC (Measure of the 3D radiation pattern of commonly used CUAS), Report including recommendations on the use of state authorized CUAS.
  - Technical characteristics and mitigation: on going in JRC, Results expected in Q4 2022.
  - operational/tactical mitigation planned for 2023
- **Expected outcome**: Risk mitigation measures to ensure the safe use of CUAS capabilities

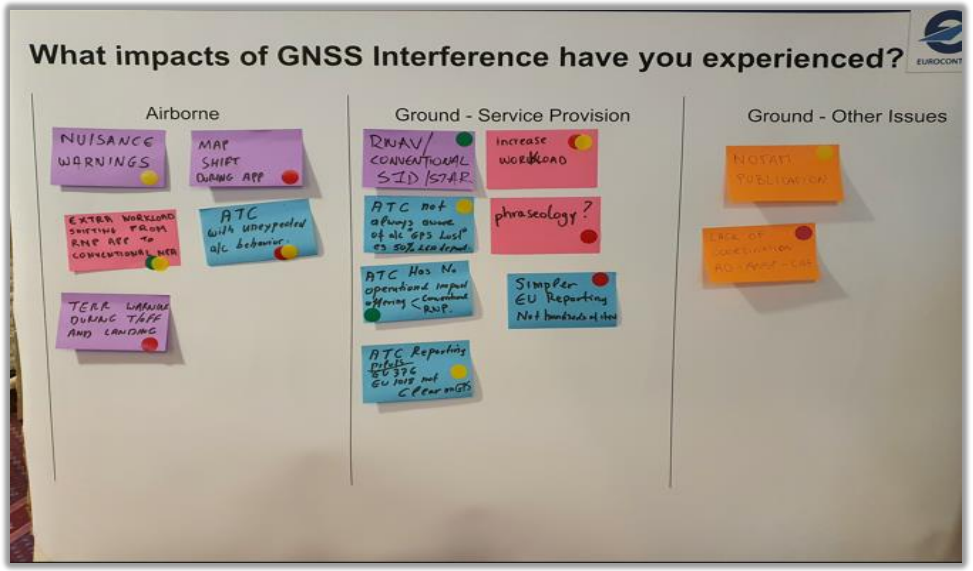






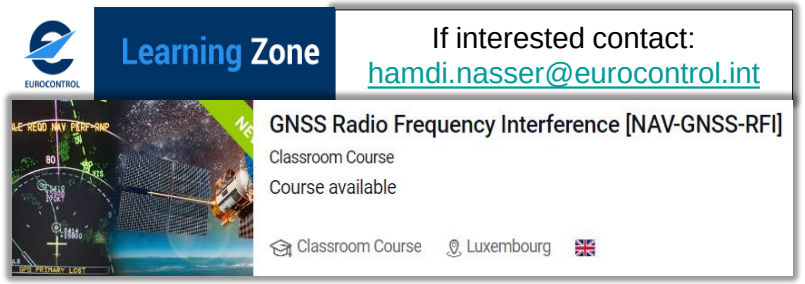
GNSS interference course - [NAV-GNSS-RFI]

- GNSS vulnerabilities - Day 1 Morning
  - Overview of the different sources of GNSS errors
  - GNSS Interference sources and classification
- Impact of GNSS interferences - Day 1 afternoon – Day 2 morning
  - Group work and discussion: This module aims to encourage the audience to exchange their experiences and to focus on the main problems they are facing with regard to GNSS interferences.
  - GNSS RFI impact on airborne and ground systems
  - Impact on ATM operations
- GNSS interference mitigation – Day 2 Morning - afternoon
  - GNSS threat risk assessment
  - Strategic mitigation measures
  - Tactical mitigation measures
  - Airspace concept: Contingency and reversion strategies
  - Takeaways



https://learningzone.eurocontrol.int/ilp/pages/description.jsf#/users/@self/catalogues/896269/coursetemplates/13958757/description

DAY/TIME	09:00		12:30	13:30	17:00
DAY 1	Introduction	GNSS vulnerabilities	Sources of GNSS interferences	Impact of GNSS interferences	
DAY 2	Impact of GNSS interferences		GNSS interference mitigation	GNSS interference mitigation	Debrief



Location

Aviation Learning Centre, Luxembourg

Dates

7-8 June 2023

Summary

- GNSS interferences continue to affect aviation operations and may increase further in the future
  - GNSS testing, CUAS, proliferation of jammers
  - GNSS RFI may escalate beyond “operational nuisance”
  - Importance of **automatic detection and reporting to** the relevant national authorities

- EUROCONTROL is developing monitoring capabilities
  - IOC and weekly updates: RFI detection and localisation using ADS-B
  - Objective is to move to a near real time tool and to combine with other data in order to support ATM ops
    - **Impact on operations** depends on the fleet capabilities and the available infrastructure: Importance of defining suitable contingency procedures taking into account those factors
    - Importance of **continuous monitoring** to enable **timely reaction** to a significant event and implement appropriate mitigation measures
- Exploit multi-mode strengths
  - ADS-B provides indirect **monitor** of GNSS RFI – already today
  - **Additional** aircraft, ground and space **capabilities** can provide independent confirmation
  - **Standards**: Work on going to define the “GNSS RFI detection and status downlink” functions
- Prepare the future
  - Robust **multi-sensor** positioning preventing a single point failure
  - Use of the **RFI downlink** function
- EUROCONTROL guidelines on a process for Civil-military GNSS interference testing – Coordination of state authorized GNSS RFI testing
  - CUAS study could feed the guidelines with recommendations related to the safe use of CUAS (unplanned events).