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SAFE SKIES.

SUSTAINABLE

FUTURE.

ATSEP's Role in Detecting, Diagnosing, and Mitigating GNSS RFI for a Human-Centric ATM System

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Agenda

Understanding GNSS RFI

GNSS RFI Detection & Mitigation Techniques

Importance of ATSEP in GNSS RFI management

Operational demands, Outages and Challenges

ATM Operational Environment

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Who we are? IFATSEA

About IFATSEA

- IFATSEA is the authoritative voice on the competence of air traffic safety electronics personnel. Using our strong global network, we actively contribute to the improvement of air traffic safety performance.

Our Vision

- IFATSEA is the authoritative voice on the competence of air traffic safety electronics personnel. Using our strong global network, we actively contribute to the improvement of air traffic safety performance.

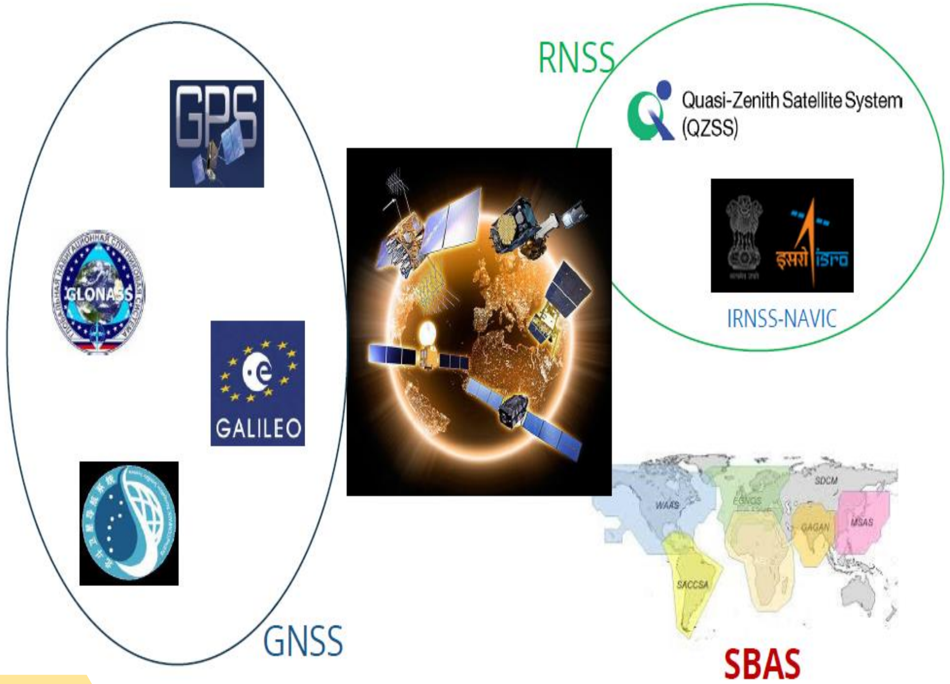
Working with other ATM stakeholders

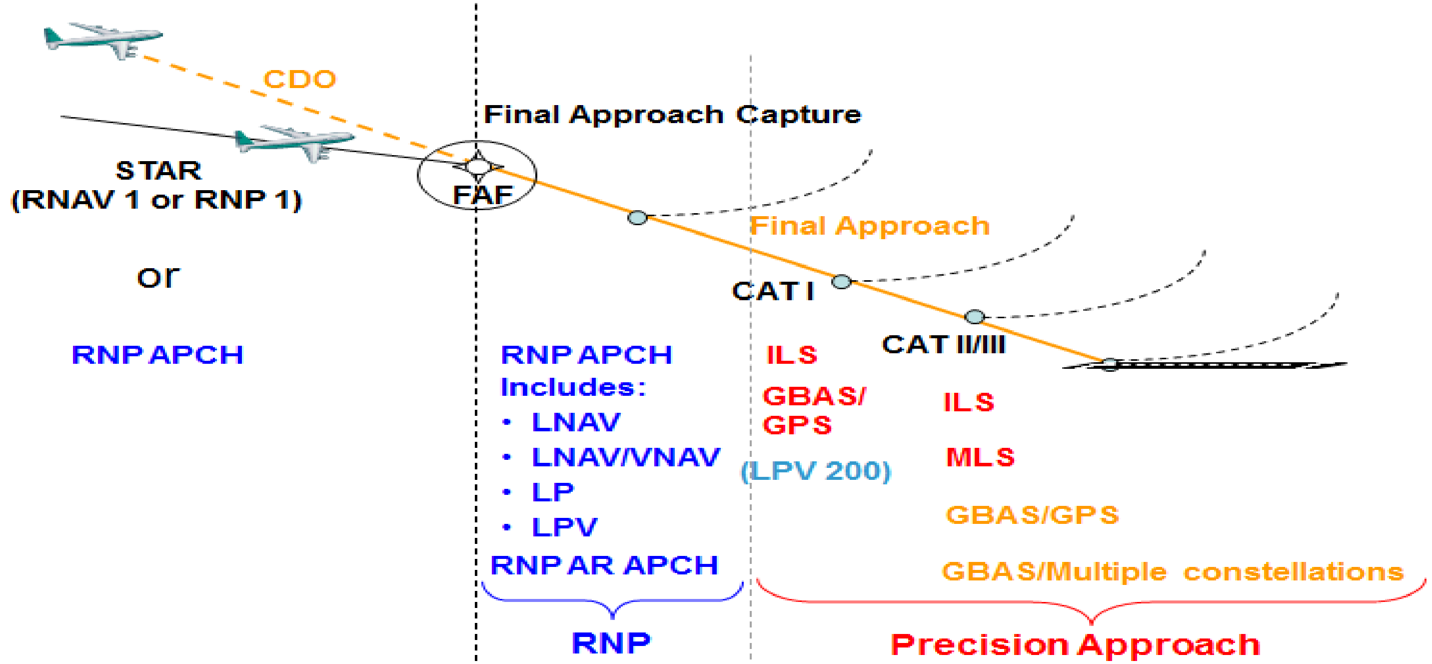
- Working Together with ICAO, IFATSA was strongly involved in developing the ICAO PANS-TRG Doc 9868 and ICAO Doc 10057.

IFATSEA is "The Global Voice of Air Traffic Safety Electronics Personnel (ATSEPs) "

WHAT'S UP IN THE SKY?

Understanding





GNSS

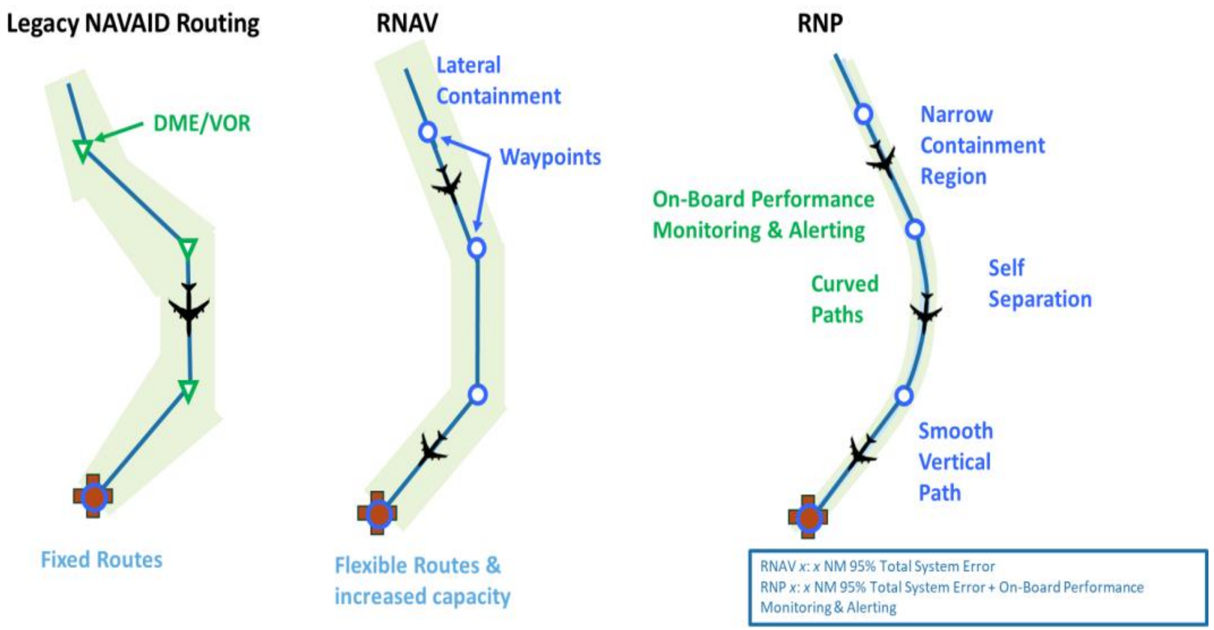
- GNSS is essential for implementing PBN and ADS-B, which bring substantial safety, capacity, and environmental benefits to ATM.
- GNSS provides the time reference to synchronize systems (e.g. communication networks) and operations in ATM.

- In most phases of flight RNAV or RNP specifications are utilized
- Approach phase of flight and navigating inside the Final Approach Fix or Point (FAF/FAP) using only the on-board navigational capabilities, then the aircraft must have On-board Performance Monitoring and Alerting (OBPMA).
- Therefore, all approach specifications are RNP.

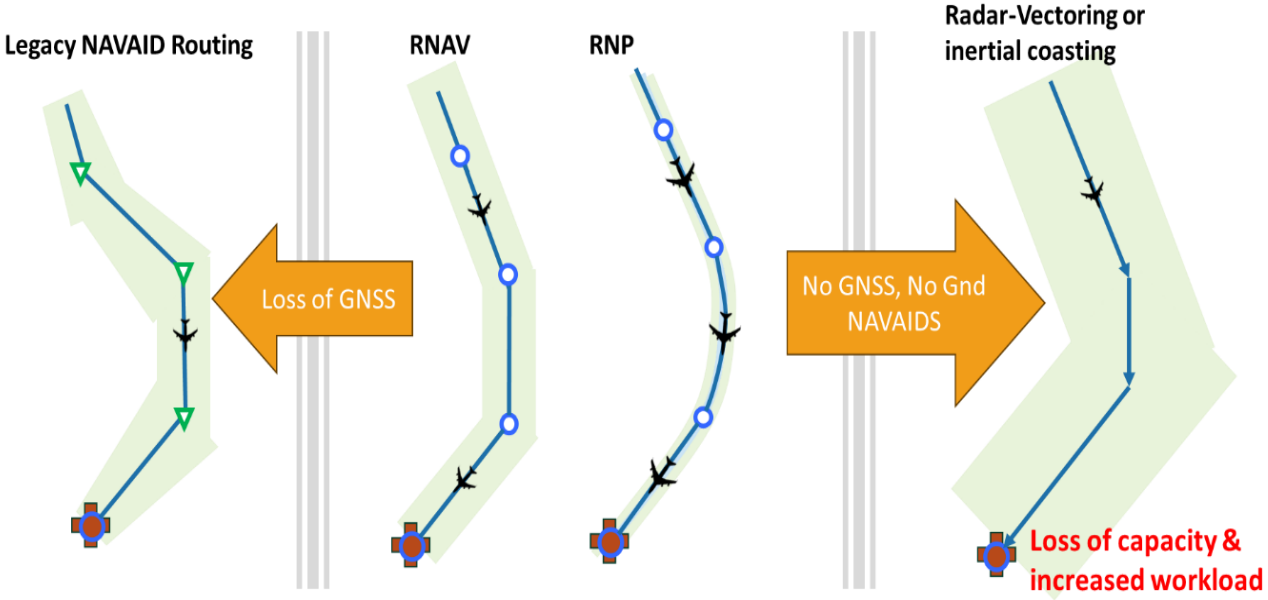
GNSS Scenarios

GNSS RFI Impact on PBN

PBN Background



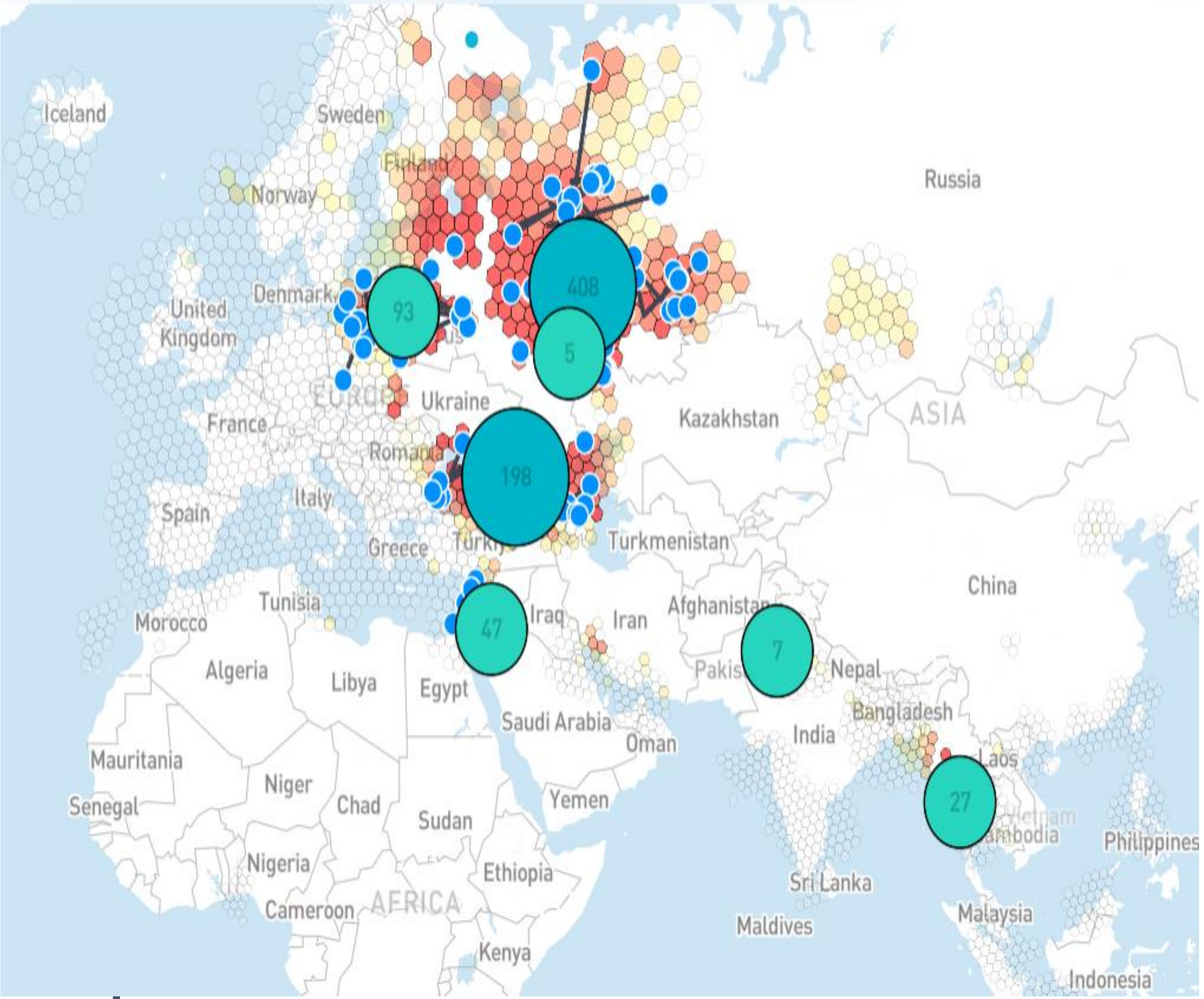
Benefits of PBN. Legacy routing requires the aircraft track to follow the physical layout of the NAVAIDs.

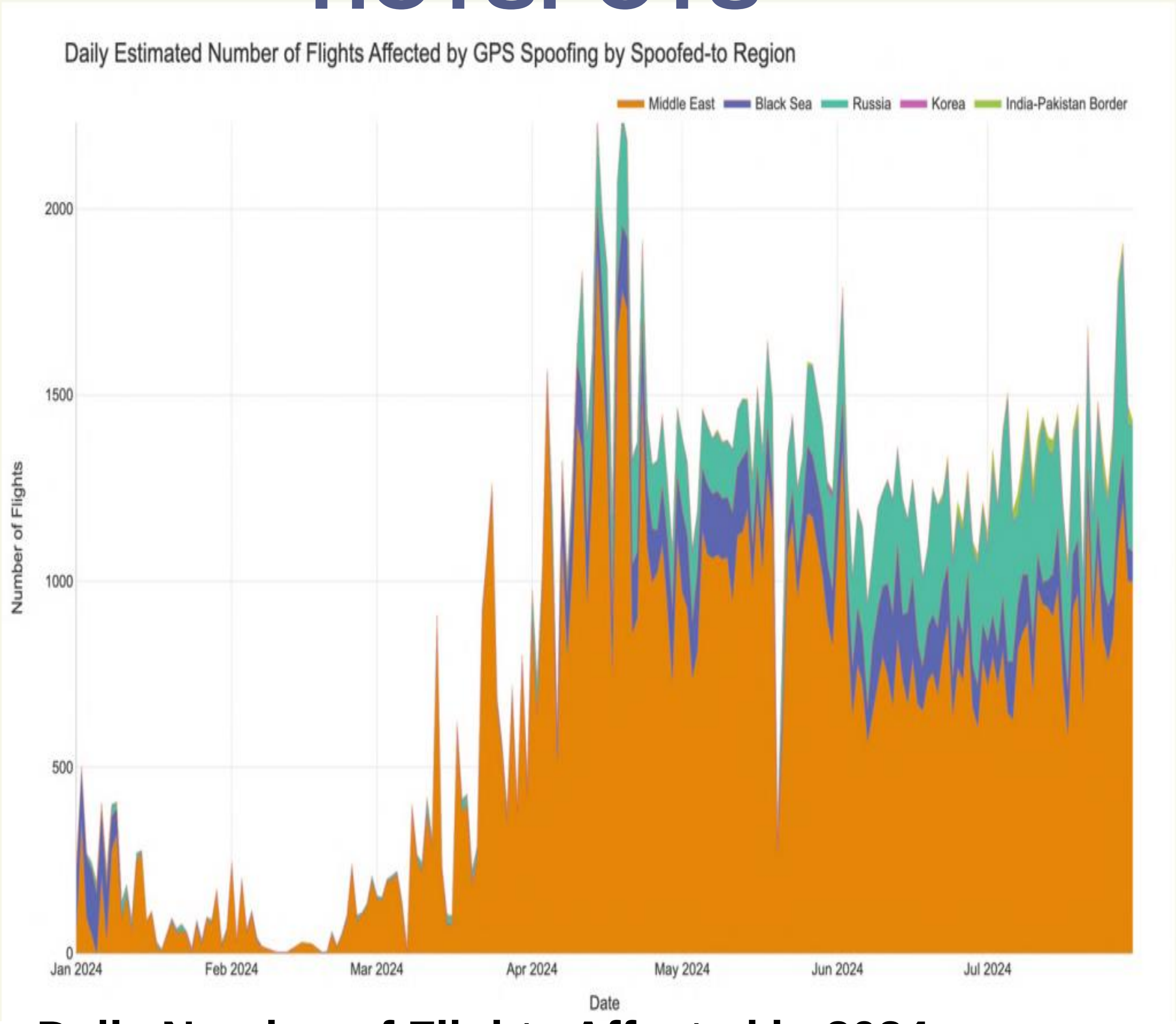


In areas with a strong infrastructure of terrestrial NAVAIDS, RNAV can fall back on that during RFI.

GPS spoofing has led to degradation to multiple aircraft systems, demonstrating that GPS has become a single point of failure.

GNSS RFI HOTSPOTS



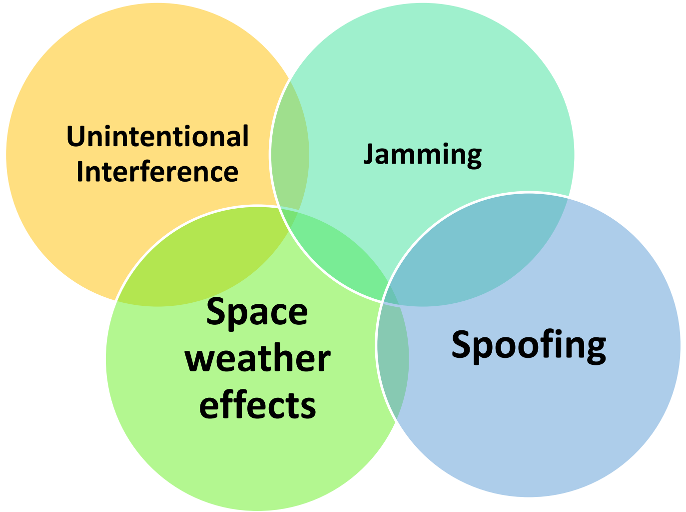


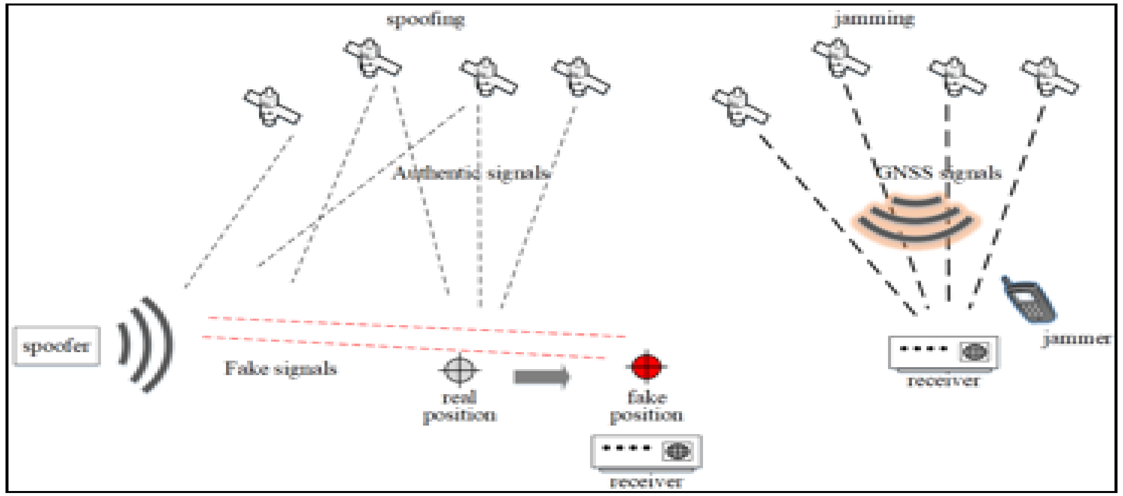
Daily Number of Flights Affected in 2024

Source: OPS Group

Sources of GNSS RFI

Sources



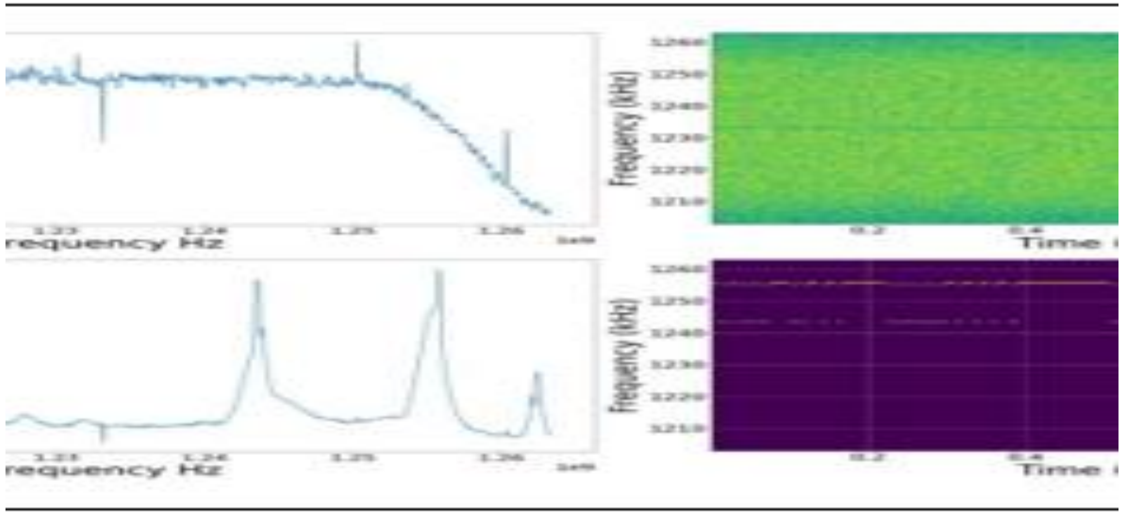


Different GPS Jammers

Portable GPS Jamming Device

Jammer mounted in an SUV

Readily available: Jammers for your car.



Original GNSS signal (top) and jammed signal (bottom) spectrum (left) and time-frequency (right) plot

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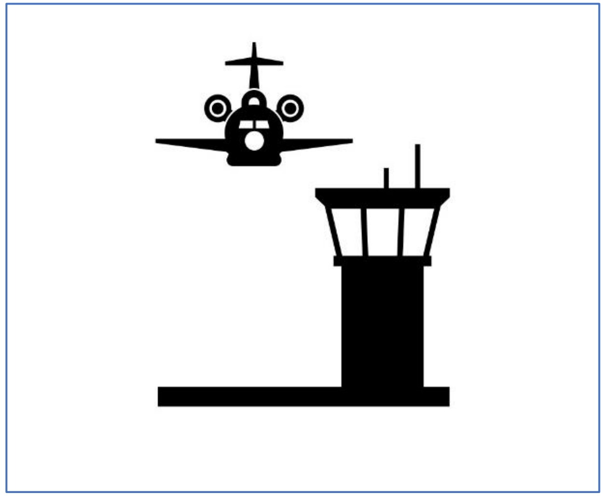
Operational Demands



Airline

- Safe
- Simple to fly
- Shortest Possible Track
- Noise abatement
- Fuel Saving

ATCO

- Safe
- Simple to use
- High efficiency

Airport Operator

- Efficiency
- Capacity
- Safety

Critical Parameters ANSP

- Required Navigation Parameters(RNP)
- Required Communication Parameters (RCP)
- Required Surveillance Parameters(RSP)

Effects of GNSS Outages on Aviation Operations

Navigation System Failures:

- Loss of GNSS-based waypoint navigation, RNAV, and RNP capabilities, including RNP-AR approaches.
- Inconsistent or misleading aircraft position, altitude, and speed data on navigation displays or EFBs.

Surveillance and Safety System Disruptions

- Loss or corruption of ADS-B functionality, affecting traffic and terrain awareness.
- Malfunctioning TAWS, leading to spurious "PULL UP" alerts and uncoordinated climbs.
- Loss of ACAS (Airborne Collision Avoidance System), increasing collision risks.

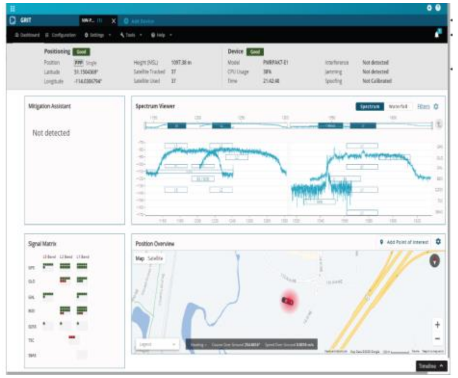
Flight Guidance and Control Issues:

- Inconsistent flight guidance, causing route divergence, un commanded turns, and deviations from ATC clearances.
- Potential airspace infringements, loss of traffic separation, and insufficient terrain/obstacle clearance.

Operational and Safety Risks:

- Increased workload for ATC and flight crews.
- Reduced airspace efficiency, capacity, and operational delays.
- Elevated safety risks due to system degradation and misleading alert

GNSS RFI Detection Methods



GRIT Simulation

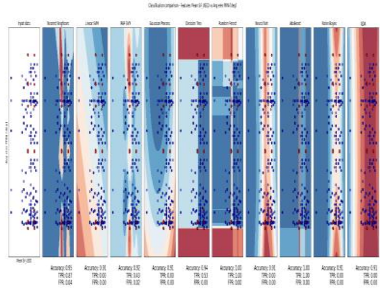
☑ EUROCONTROL's GRSS Receiver Interference Testing (GRIT) study.

☑ The study focused on **C/N0**, pseudorange, Dilution of Precision (DOP), and Protection Levels (HPL/VPL) as key observables.

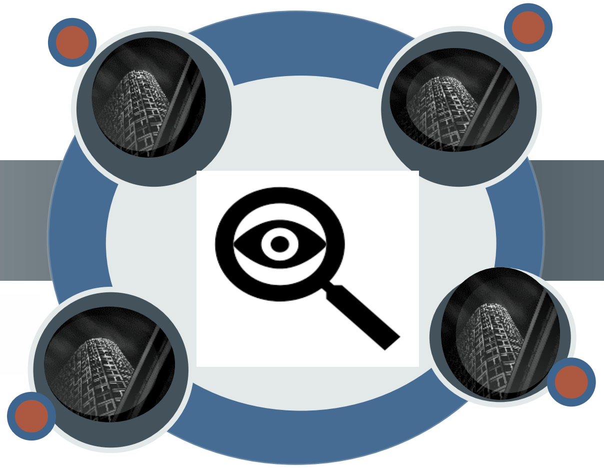
Airborne Detection Methods

☑ RX Observables

SVM (Support Vector Machine) Classification:
, RANSAC (RANdom SAmple Consensus):
, Kalman Filter & Entropy:

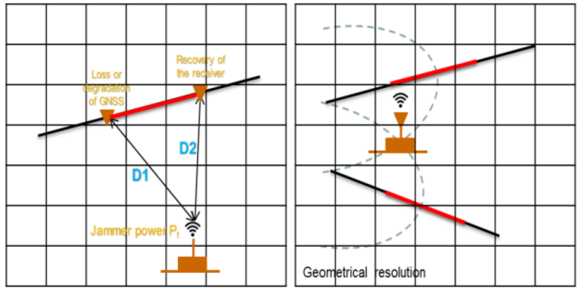


- UAV-Based Detection
- Pilot reports
- Onboard detection tools



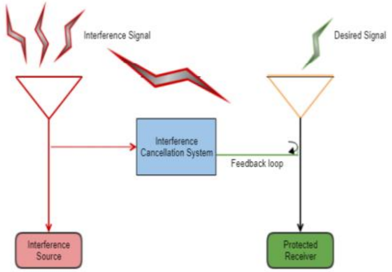
Ground Detection

- ADS-B-Based Detection
- Collaborative Detection & Localization using **Power Difference of Arrival (PDOA)**



OEM developed Methods

- Antenna Arrays
- Digital RF Filtering and Shielding
- spectrum analyzer to detect abnormal power levels in GNSS frequency bands.



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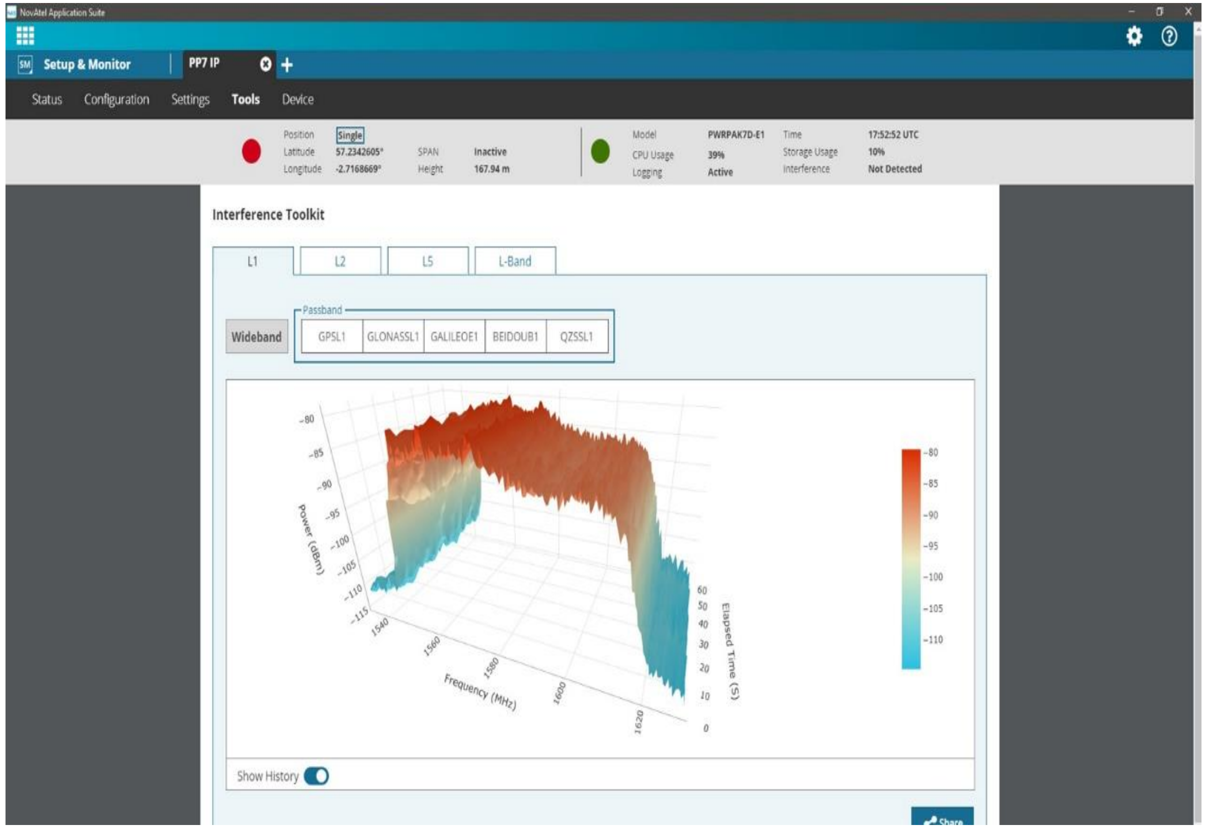
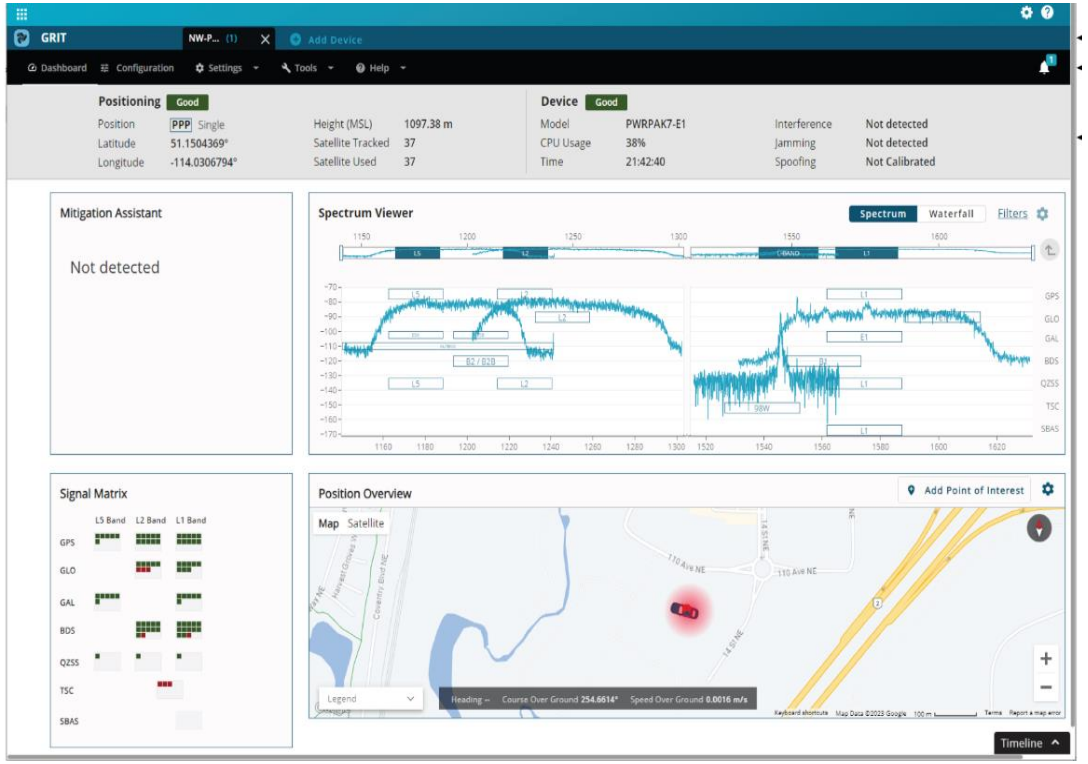
GRIT Simulation Platform for Detection of GNSS RFI

NovAtel receivers Tool Kit



EUROCONTROL's GRSS Receiver Interference Testing (GRIT)



✈ The spectral analysis tools on all [NovAtel OEM7 receivers]() show how much signal power is sensed across the different GNSS frequency bands.

✈ If an interference signal is present, it can be seen in the spectral analysis output plot.

Key Observables:- ✈ C/N0, pseudo range, Dilution of Precision (DOP), and Protection Levels (HPL/VPL)

✈ C/N0 as Primary RFI IndicatorC/N0 degradation is directly proportional to interference power and spectral distribution.

✈ The GRIT study validates C/N0 as the most reliable

Ground Detection of GNSS RFI via ADS-B and NIC Monitoring Tool

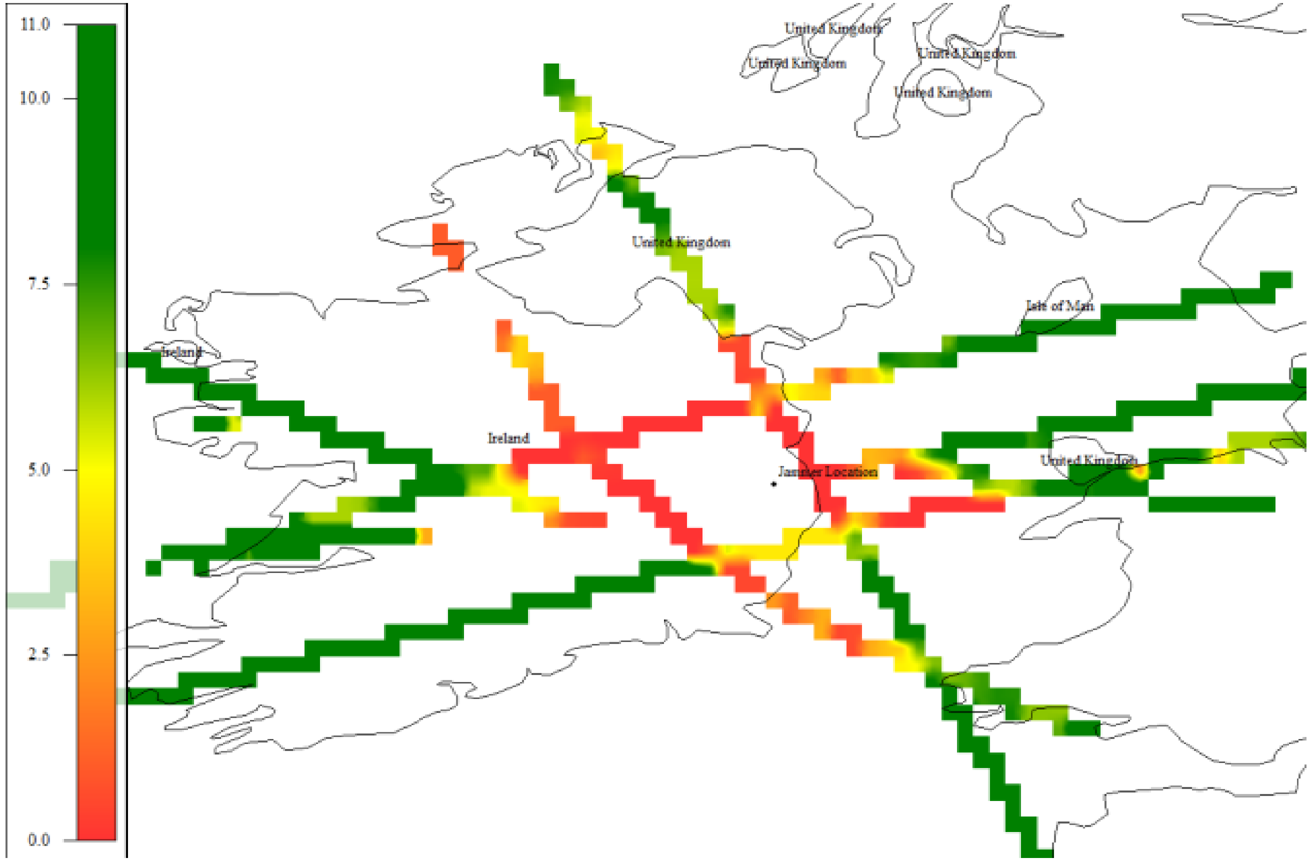
✈The ADS B Navigation Integrity Category (NIC), helps identify onboard GNSS issues.

Key Idea

✈ **NIC is derived from the Horizontal Protection Level (HPL)**,

✈ Under normal conditions, aircraft with an **unobstructed sky view** maintain **HPL values below 0.2 nautical miles**, corresponding to a **NIC value above 7**.

✈ If multiple aircraft report degraded NIC values in a specific area, **GNSS interference is likely the cause**.



Navigation Integrity Category (NIC) degradation in the jammer proximity.

Green dot :unaffected portion of the aircraft trajectory

Orange: aircraft trajectory with low to moderate JSR,

Red: aircraft trajectory with high JSR(Jammer to Signal)

Methodology for RFI Source Localization

The difference in received interference power at points of signal degradation and recovery can be used to estimate the location of the RFI source, **this is known as the Power Difference of Arrival (PDOA) for RFI Localization**:

Mathematical Model for Interference Power & Distance Estimation

The interference power at the receiver is modeled as:

$$P_t = \left(\frac{4\pi D}{\lambda}\right)^2 \cdot \frac{P_r}{G_t G_r}$$

$$P_{r_{loss}} = \left(\frac{\lambda}{4\pi D_1}\right)^2 \cdot G_t G_r P_t$$

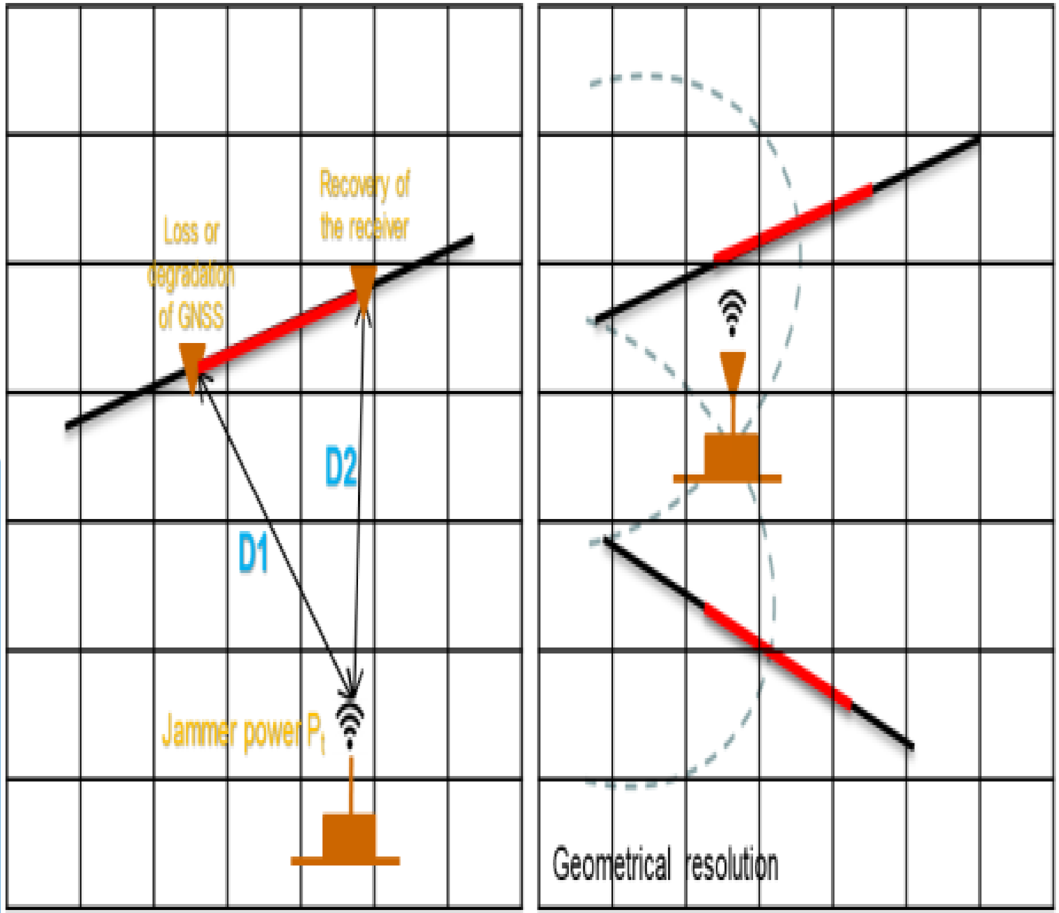
$$P_{r_{Recovery}} = \left(\frac{\lambda}{4\pi D_2}\right)^2 \cdot G_t G_r P_t$$

D=distance between source & receiver, **Pt**=Transmitted interefernce power, **Gt**=Transmitting antenna Gain, Pr=Received interference power

***D*1** is the distance between the interference source and the receiver position when it provides a degraded solution or losses PVT. ***D*2** is the distance between the interference source and the receiver position when it recovers from the interference.

$$\frac{P_{r_{Recovery}}}{P_{r_{loss}}} = \left(\frac{D_1}{D_2}\right)^2$$

The **ratio of received power at loss and recovery points** helps determine the **relative distances to the interference source**:



Interference source geo localization using a PDOA approach.

Airborne RFI Detection Methods

Develop and evaluate airborne techniques for detecting GNSS RFI using C/N0 metrics, tested against various jammer types (CW, Chirp, Noise-like) in dynamic scenarios.

01

SVM (Support Vector Machine) Classification:

✈ Classifies RFI vs. non-RFI events using Machine Learning.
✈ Features: Mean C/N0, Peak-to-peak C/N0, number of satellites (SVs), and PRN elevation

02

RANSAC (RANdom Sample Consensus)

✈ Detects C/N0 anomalies relative to expected elevation-dependent behavior
✈ Curve Fitted to a quadratic polynomial

03

Kalman Filter & Entropy

✈ Estimates C/N0 and entropy of residuals, sensitive to RFI-induced C/N0 variations.

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PBN implementation status in India

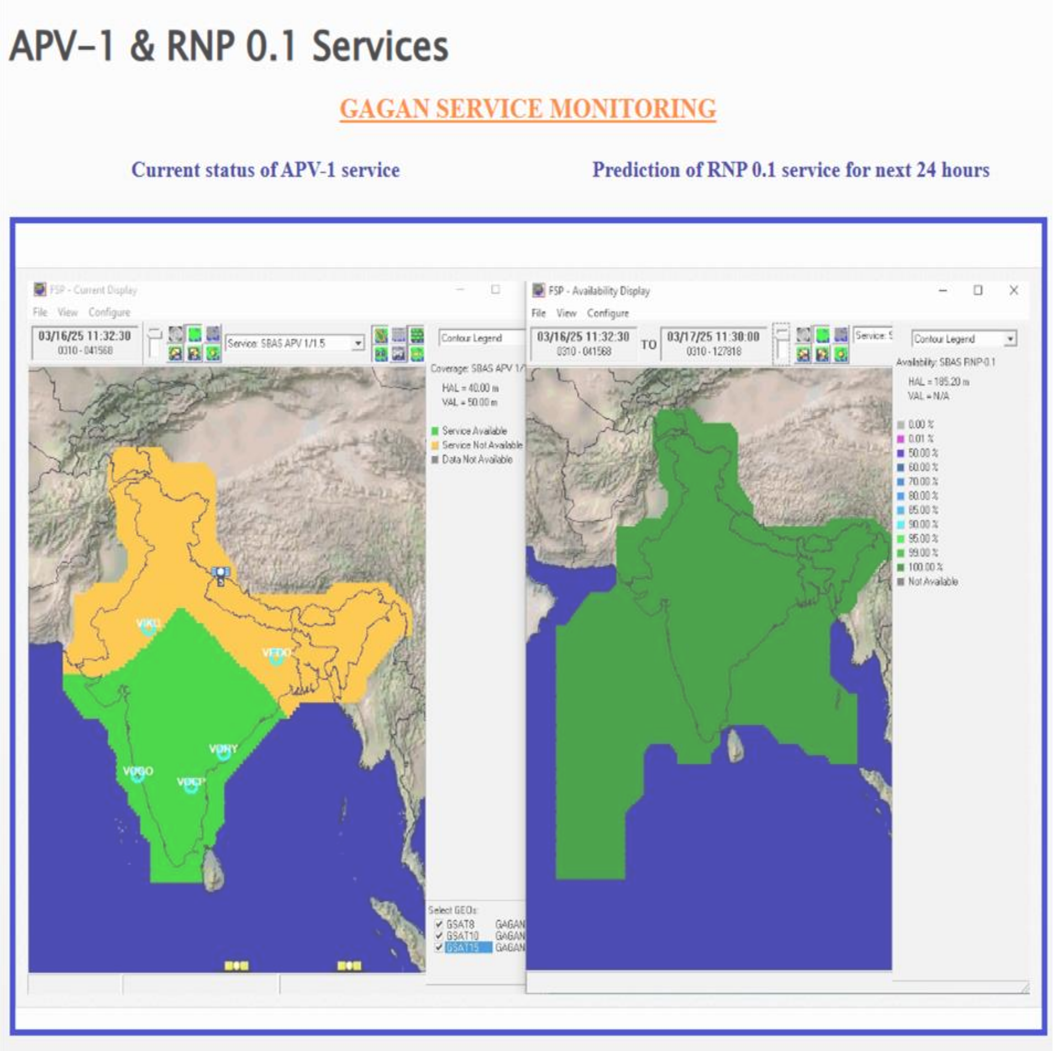
- ATS Routes

Routes	Conventional ATS route	PBN routes (RNAV 10)	Total
International	49	37	86
Domestic	344	63	407
Grand Total	393	100	493

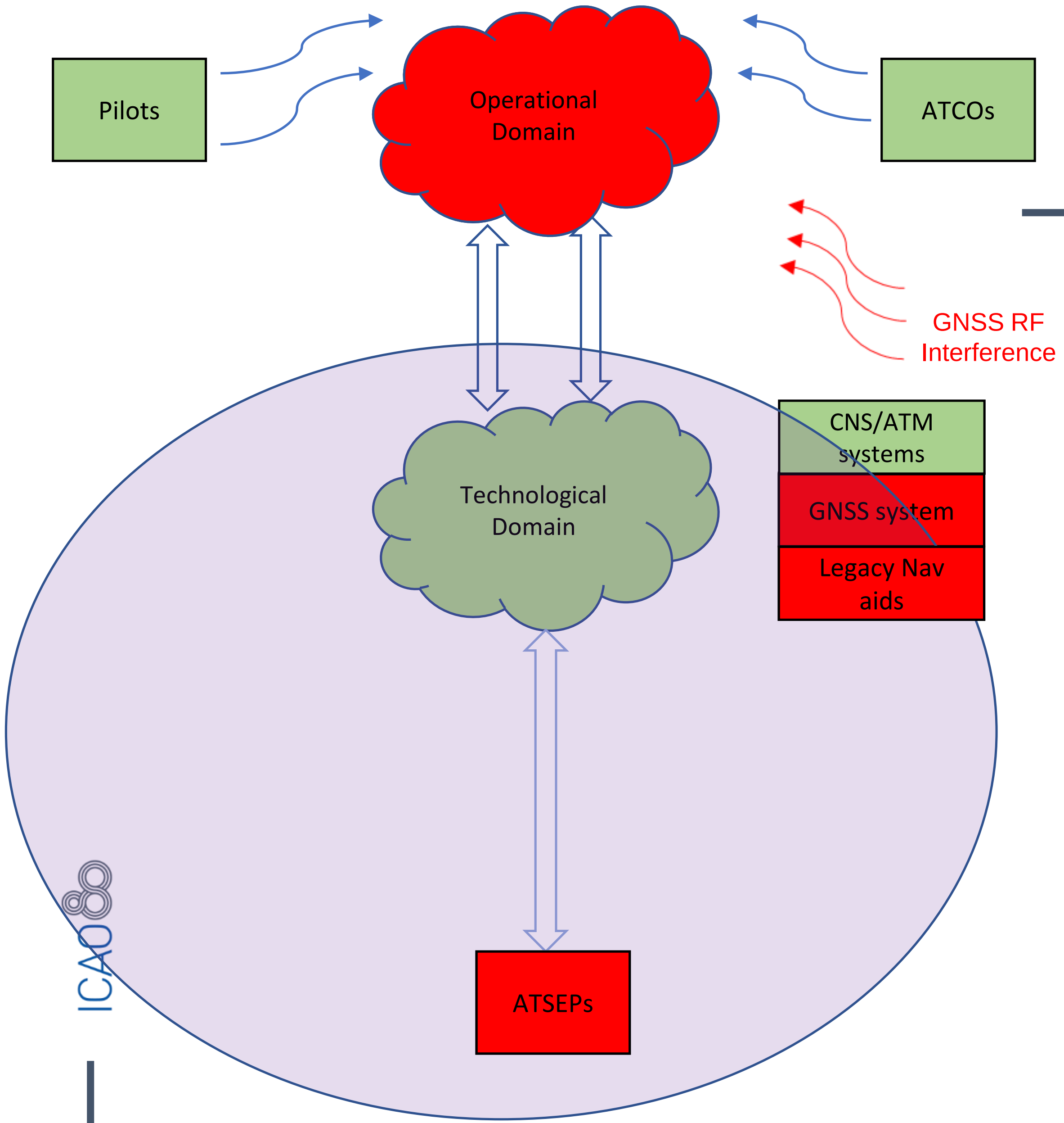
- AAI has promulgated 22 LPV (GAGAN) Procedures, 129 RNP Approach Procedures (LNAV, LNAV/VNAV and PBN SIDs and STARs at 14 Airports.

The GPS Visibility Tool has been developed. Every day at 0001 UTC, a NOTAM is issued listing the duration when RAIM holes are likely to occur in the next 24 hours at every airport. The tool is hosted on the AAI website to provide users with online RAIM prediction capability.

RAIM Prediction



ATM Operational Environment



✈ To maintain the operation's continuity & fewer disruptions on operation the ATSEPs should keep both the GNSS System & Legacy Navaid System in functional.

✈ Subsequently

- The load is shifted to ATSEP's

Subsequent affects

☑ Increased Workload

☑ Coordination Challenges

☑ System Adaptation

☑ Stress and Pressure

☑ Training and Preparedness

ATSEPs Multi-tasking

Why Multitasking is Critical for ATSEPs?

- Air traffic management operates 24/7, so ATSEPs must juggle multiple responsibilities under pressure.
- A small error in managing one system can affect the entire air navigation infrastructure, leading to delays or even safety risks.
- Their ability to multitask ensures continuous, safe, and efficient air traffic operations.

Key Areas of Multitasking for ATSEPs

In the case of the GNSS denial environment, ANSPs should switch to conventional/fallback procedures viz, Ground-based navigational systems.
From an operational perspective, it is desired to continue providing nav services during GNSS outages with higher accuracy and tighter integrity alert limits.

System Monitoring and Maintenance: ATSEP responsibility spans real-time monitoring, interference identification, alternate navigation support.

Coordination with Air Traffic Controllers and Engineers: coordinate with ATCOs & stakeholders

Emergency Response and Crisis Management: Identify the problem, implement backup solutions, and restore normal operations & manage multiple failures simultaneously

Compliance and Documentation: Follow strict safety regulations while handling multiple tasks.

Cybersecurity and Technological Upgrades: The legacy nav signals are standardized and prone to interference with SDR . Managing cyber threats becomes crucial with legacy systems are heavily relied upon.

THANK YOU 🙏

Dr. Chilaka Mahesh