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# GNSS RFI Mitigation

(Session 3, International Organization Perspective:
Focus on Air Traffic Management)

Gerhard Berz

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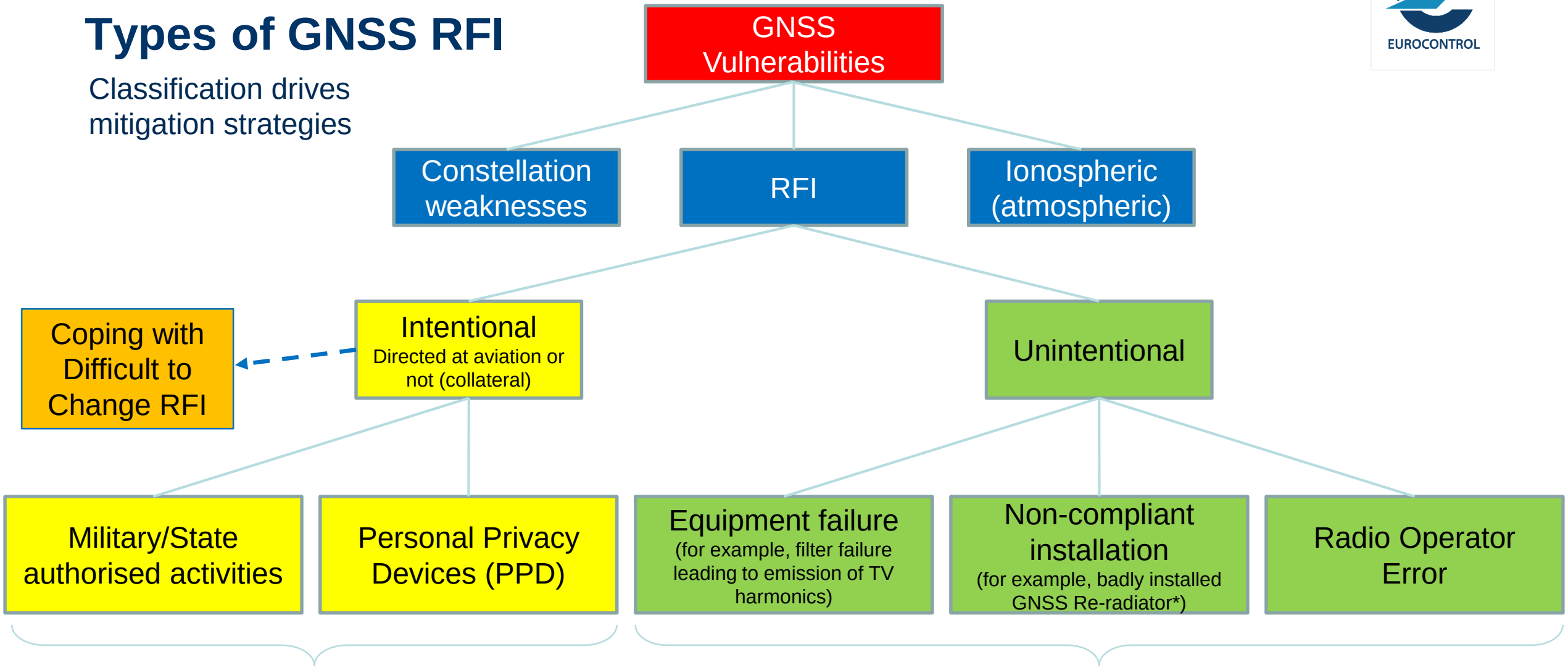
FOUNDING MEMBER SESAR JOINT UNDERTAKING

NETWORK MANAGER

# Types of GNSS RFI

Classification drives mitigation strategies



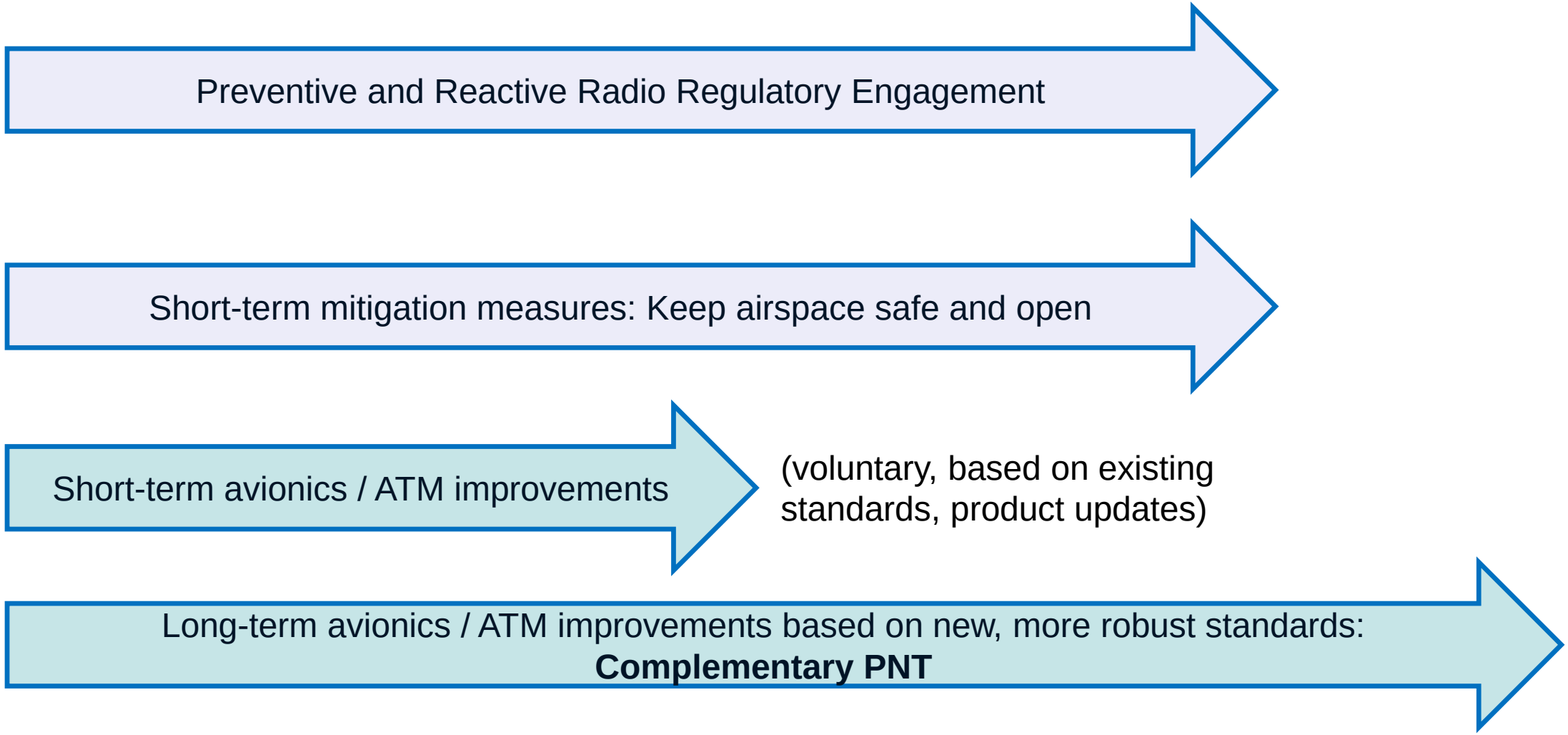

Interference whose purpose is to disrupt/mislead GNSS signal reception

***Outreach, Law enforcement against unauthorized jammers***
***Coordination of GNSS RFI testing exercises***

Spurious emissions not intending to disrupt/mislead GNSS signal reception

***Spectrum protection***
***Respecting Standards and allocated frequencies***

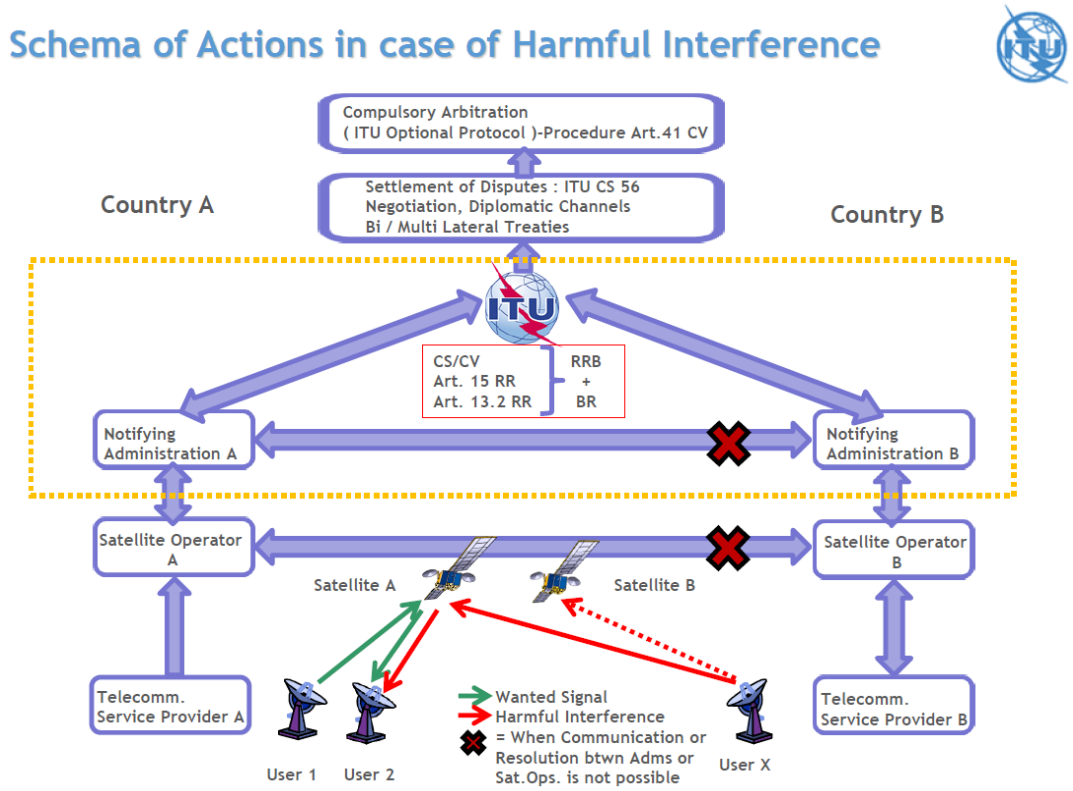
# GNSS RFI Mitigation Activities



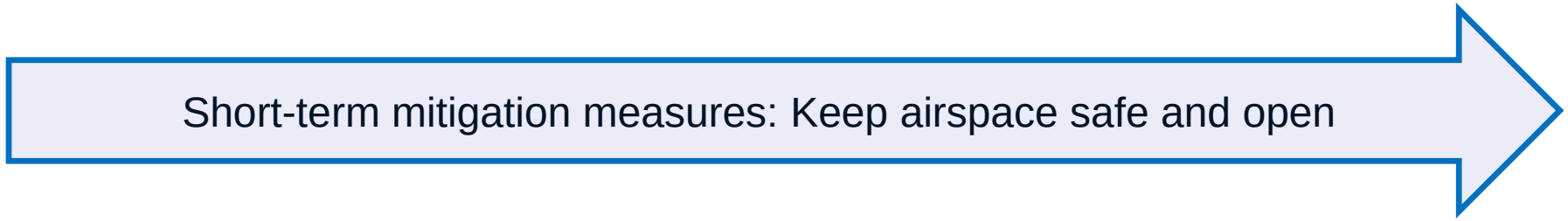
# GNSS RFI Mitigation Activities

# A “duty to complain” and use formal process

- ANConf/14 WP63 provides relevant references to ITU Radio Regulation (RR art 15)
  - What you see on the ground **is not** what you see in the air
    - ADS-B makes aircraft impact visible, **but is NOT an RF signal measurement!**
    - Need measurements of interference signals, ideally with source geolocation
    - *Build up flight inspection, other aerial work or UAS capabilities!*
    - Especially for persistent RFI sources operating 24/7
    - Need indisputable / impartial technical evidence
  - Once neighbouring State has not responded to bilateral letter, escalate to ITU Radiocom Bureau
- Further develop procedures between cooperative States (C-UAS, Military Exercises & Testing)



# GNSS RFI Mitigation Activities



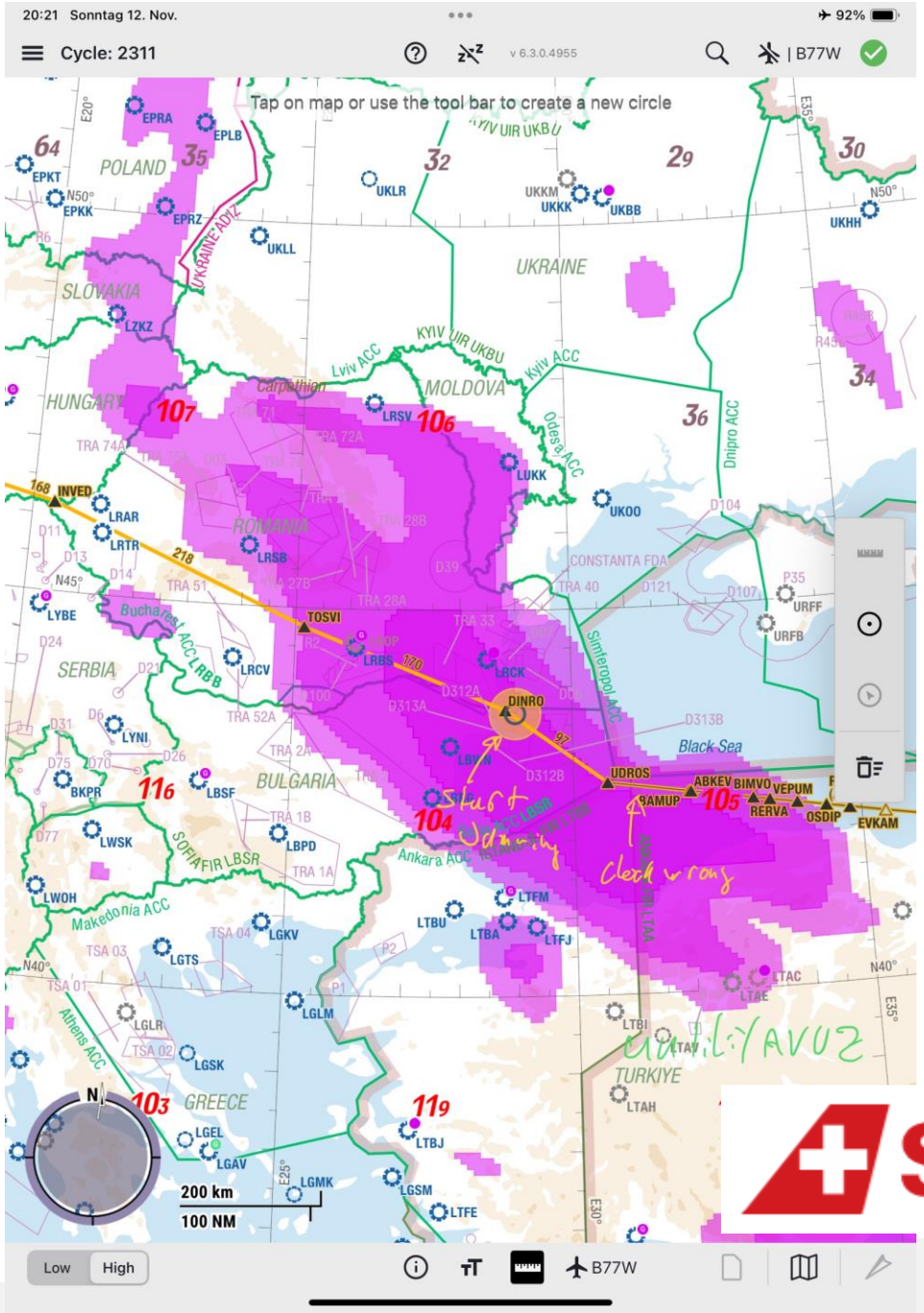
# Request from Pilots: Give me the “GPS Weather” on my EFB!

- **GNSS RFI Layer in Lido mPilot**

**Limited to “Yesterday’s GPS Weather”**

Allows pilots to deselect GPS prior to entering degraded GNSS environment to protect navigation system performance

And to reactivate GPS and associated systems once outside known zone of RFI



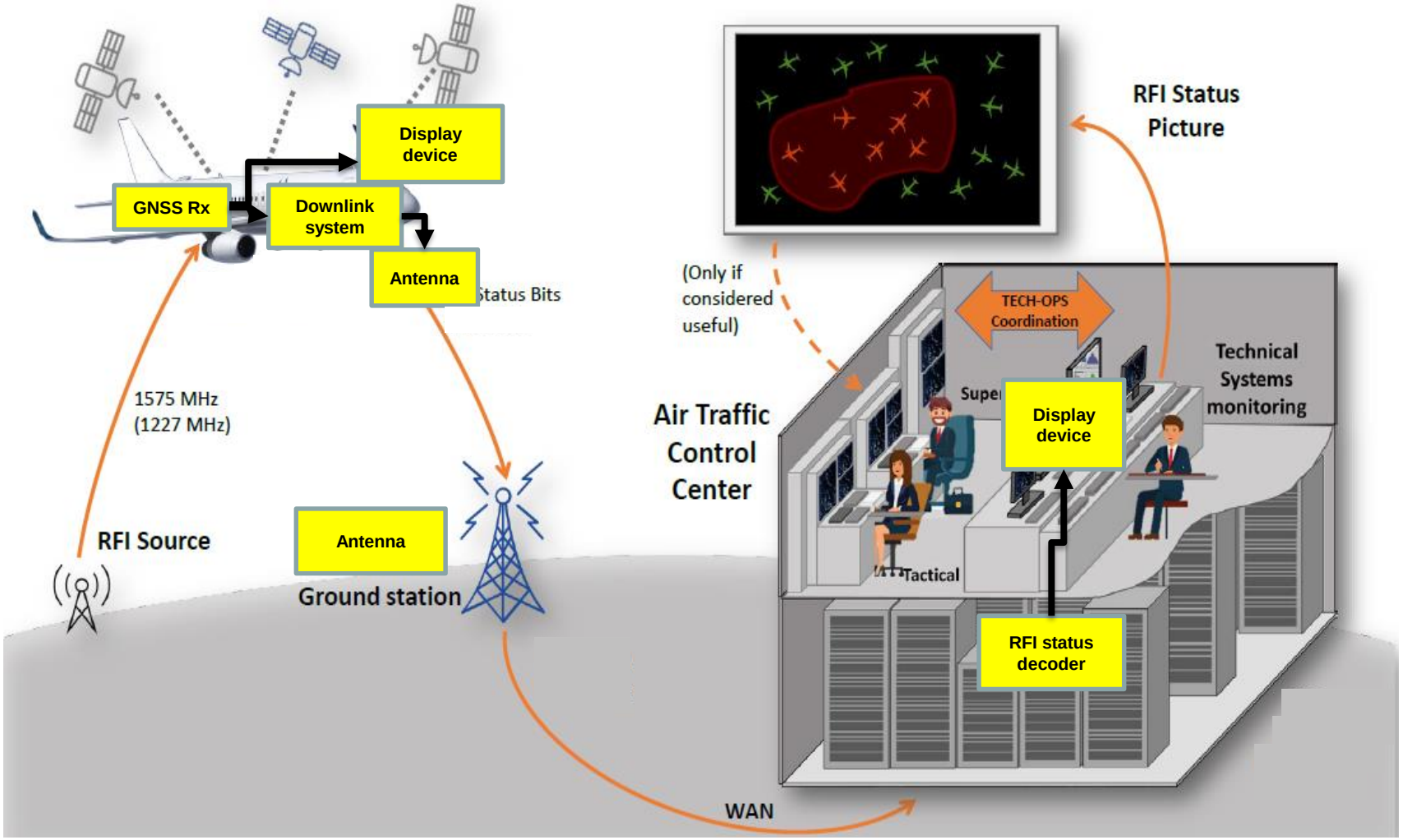
# Visualizing GNSS RFI to ensure ATC Support

## Using ADS-B low PIC today, working on standardized function in DFMC

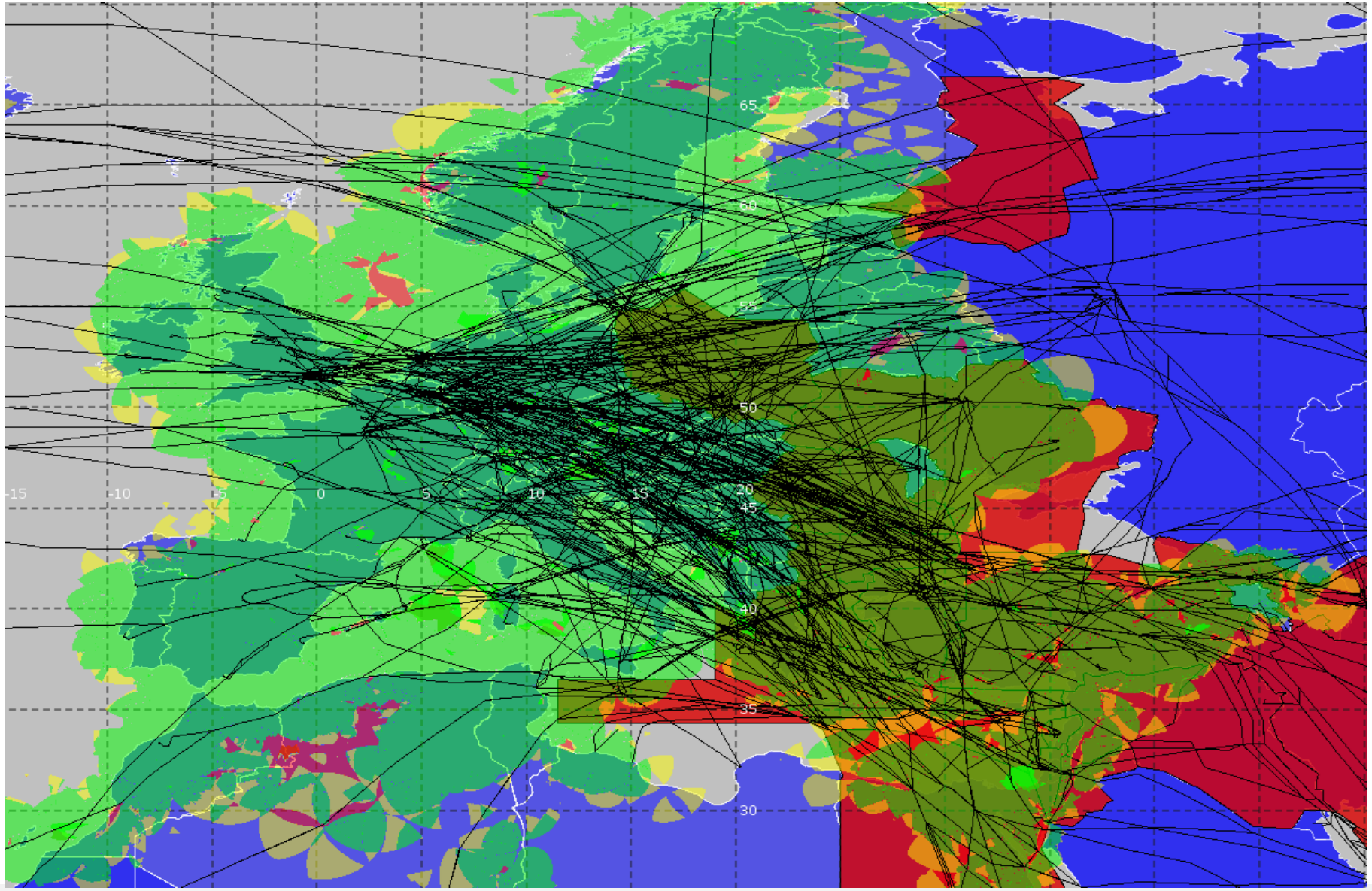
### Steps

1. GNSS Receiver **detects RFI** and **reports** it to the **ground**
2. Ground stations **process RFI status** and allow generating **an integrated RFI status** picture for multiple aircraft
3. TECH services coordinate with OPS on impacted areas and launch **operational mitigation measures**
4. Report to the **radio regulator**

***Concept of Operations under development in collaboration with most impacted ATC***



# EUROCONTROL Airspace Risk Assessment




Dark RED: FIR affected by GNSS RFI

Black: Flights crossing affected FIRs

Green: Alternative DME/DME RNAV Coverage Available

Yellow/orange: DME/DME RNAV Coverage Available but no redundancy

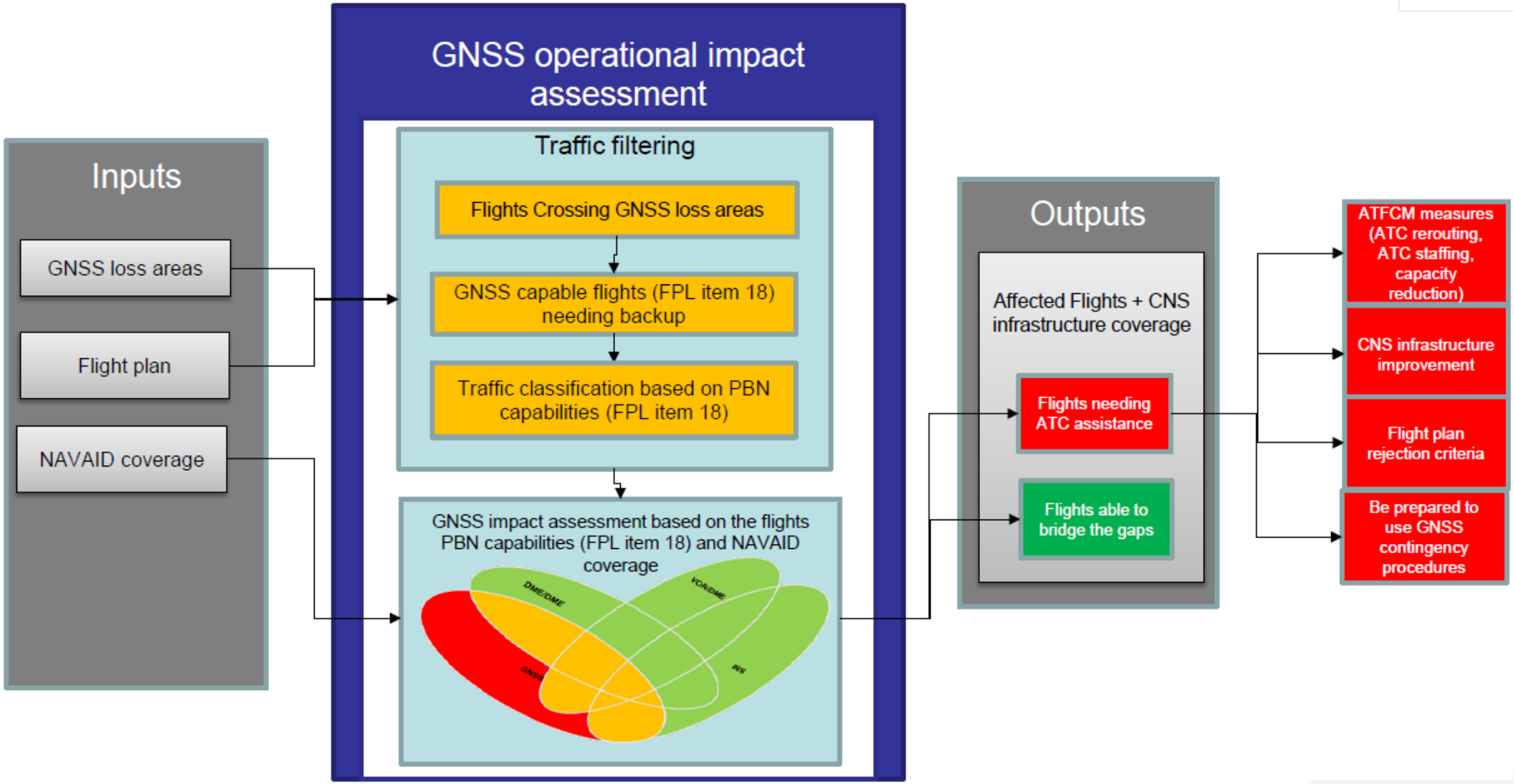
Light red: No DME/DME RNAV Coverage

# Operational Management of GNSS RFI

**OPS Logic:**

*Depending on ATC Sector, one or two aircraft needing special support is acceptable*

*If this level is crossed, capacity measures become necessary*



# Short-term GNSS RFI Mitigation Measures

- Improve reporting and operational procedures (especially Ground Prox)
- Safety Collaboration between ANSP & Operators (ANConf/14 WP61)
  - Ensure aircraft operators knows what ANSP provides to support contingency
  - Ensure aircraft are equipped to use the provided contingency services
- Provide a Resilient Operational Network (RON)
  - DME/DME based SID/STAR and ENR support whenever possible
- Ensure ILS remains available as needed
  - Ensure ILS intercept is possible without GPS (RNAV waypoints for IAF, MAPt)
- Provide a Minimum Operational Network (MON)
  - VOR/DME for non DME/DME equipped airspace users to enable safe landing
- Ensure CNS/ATM infrastructure is robust against compromised GNSS time

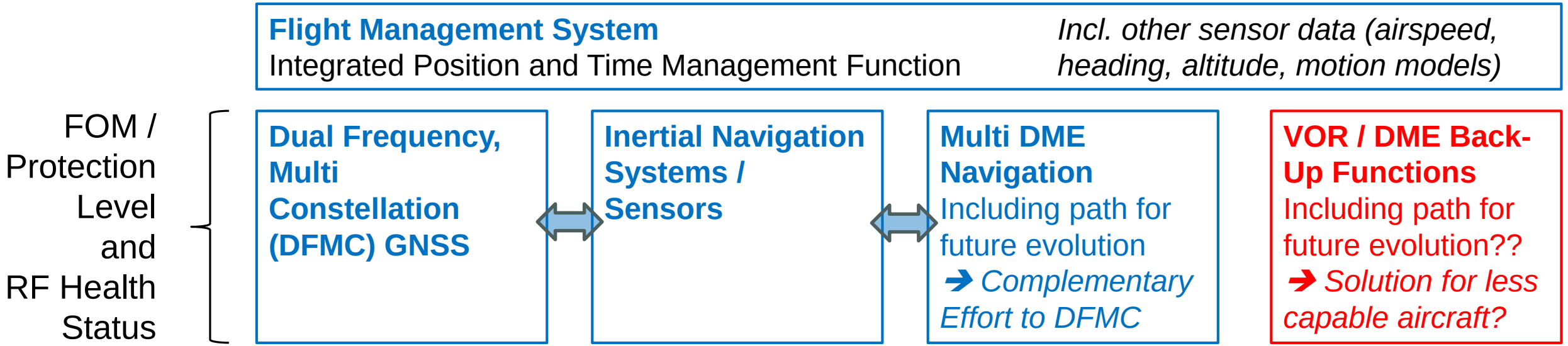
# GNSS RFI Mitigation Activities

Long-term avionics / ATM improvements based on new, more robust standards:
**Complementary PNT**

# Moving towards Complementary Resilient Navigation

## (ICAO Assembly Resolution 41-8C)

- Need “all sensors” interoperable integrity
  - More than multi-sensor: cross-check sensors for anomaly detection
  - Propagate robust position and time to all systems including ADS-B
  - Develop robust timing and time synchronization
- Similar principles can apply to SUR position integration
  - Compare ADS-B to SSR / MLAT position



# Moving towards Complementary Resilient Navigation

## (ICAO Assembly Resolution 41-8C)

- Rejuvenate DME: Move from DME/DME to Multi-DME Navigation (including INS)
  - Develop DME network balancing criteria, i.e. know how many DME we really need
  - Standards ground-work ongoing:
    - EUROCAE WG-107 DME Infrastructure supporting PBN
    - RTCA SC227 / EUROCAE WG85 Navigation Standards
    - ICAO FLTOPS PBN Manual / Navigation Specifications

Need to discuss necessary balance of space / air / terrestrial capabilities!

- Push for equipment upgrade alongside DFMC GNSS Upgrade
  - Ongoing initiatives: RTCA SC159 / EUROCAE WG62, ED-259B DFMC GNSS Receiver MOPS
    - New requirement for GNSS to recover after encountering RFI
    - RFI detection and reporting output on L1/E1 and L5/E5 (Validation ongoing / ADS-B downlink requested)
    - Authentication: SBAS and Galileo OSNMA
    - Spoofing ad-hoc considering further improvements
    - Maintain redundant GNSS modes in A-RAIM
  - EU Space Programs: RFI detection using LEO
  - ITAR changes: enabling use of advanced antenna systems (CRPA)

# EUROCAE WG107:
# DME Supporting PBN Positioning

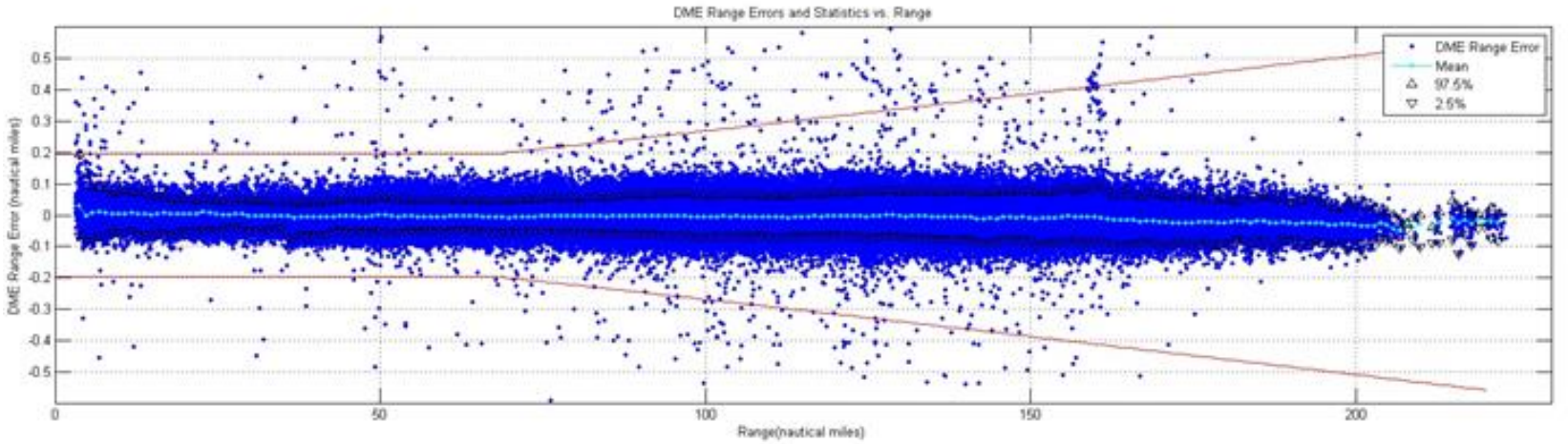
- Giving credit to DME equipment performance improvements since the minimum standards were written in the 1990's

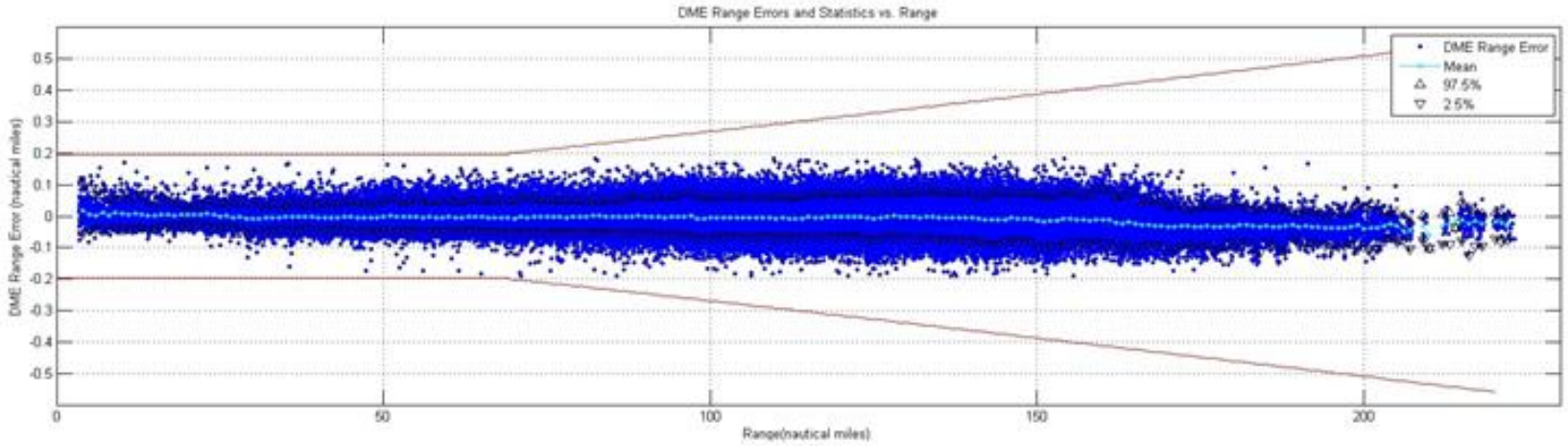
- Update of ED57, DME Transponder MOPS (Minimum Operational Performance Standard)
- New MASPS for DME supporting RNP (Minimum Aviation System Performance Standard)

- To be compatible with RNP/RNAV MASPS, DO 236D / ED-75E
- To be compatible with ICAO PBN Manual Doc 9613
- To provide one acceptable basis for State Authorization of optional use of DME in PBN
- To support move from DME/DME to Multi DME Navigation (all in view)

# DME Signal in Space Performance / In-Flight Data

## Slant Range Accuracy up to 200NM




Data from several European State DME's at around FL200

Full raw dataset: 797,505points

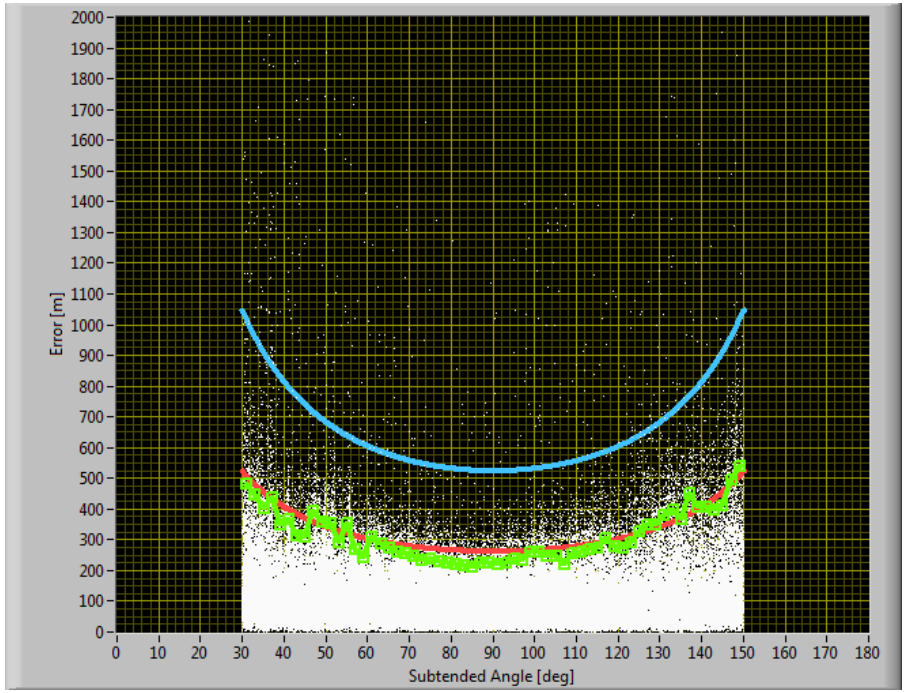
20 sec filter dataset: 413,808 points

Data aggregated for all stations

Results similar for a more recent, low altitude data set

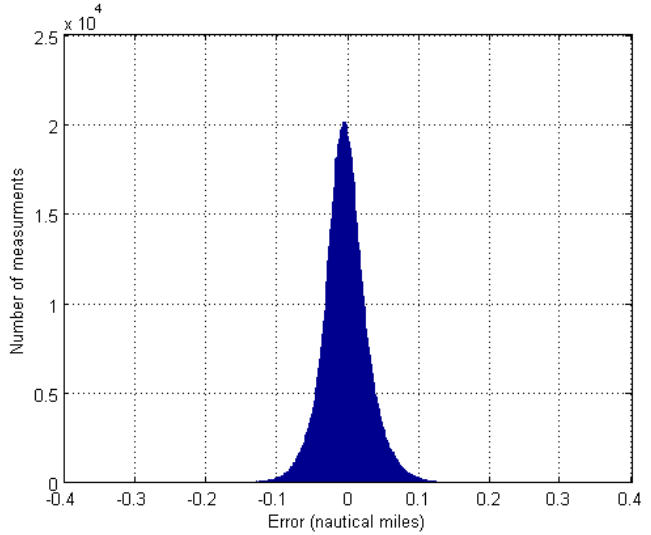
# DME Signal in Space Performance / In-Flight Data

## Slant Range Accuracy

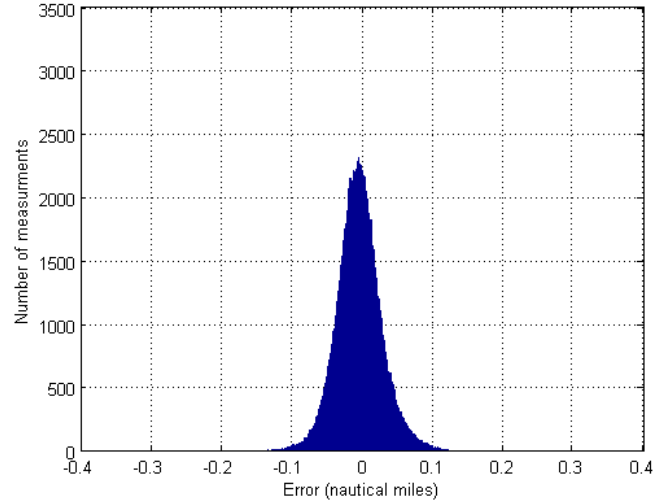



- Measured accuracy twice better than standards
  - Range error : $2\sigma < 0.1$NM
  - DME/DME NSE: $2\sigma < 0.3$ NM

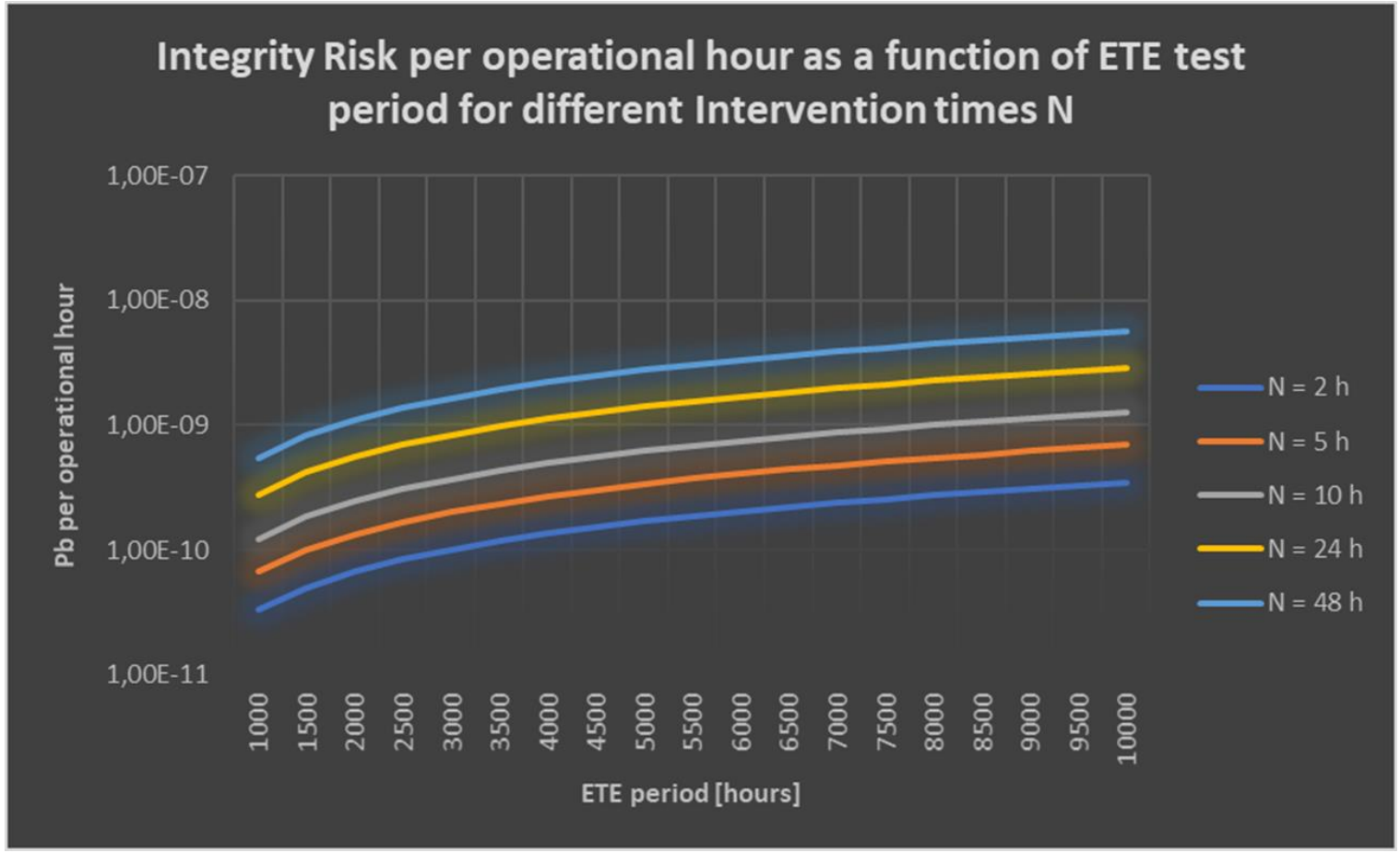
- Without 20 s filter applied:
  - Mean = -0.0038 NM (-7.04m)
  - Standard deviation = 0.0333 NM (61m)




- With 20 s filter applied:
  - Mean = -0.005001NM (-9.26 m)
  - Standard deviation = 0,0322 NM (59m)

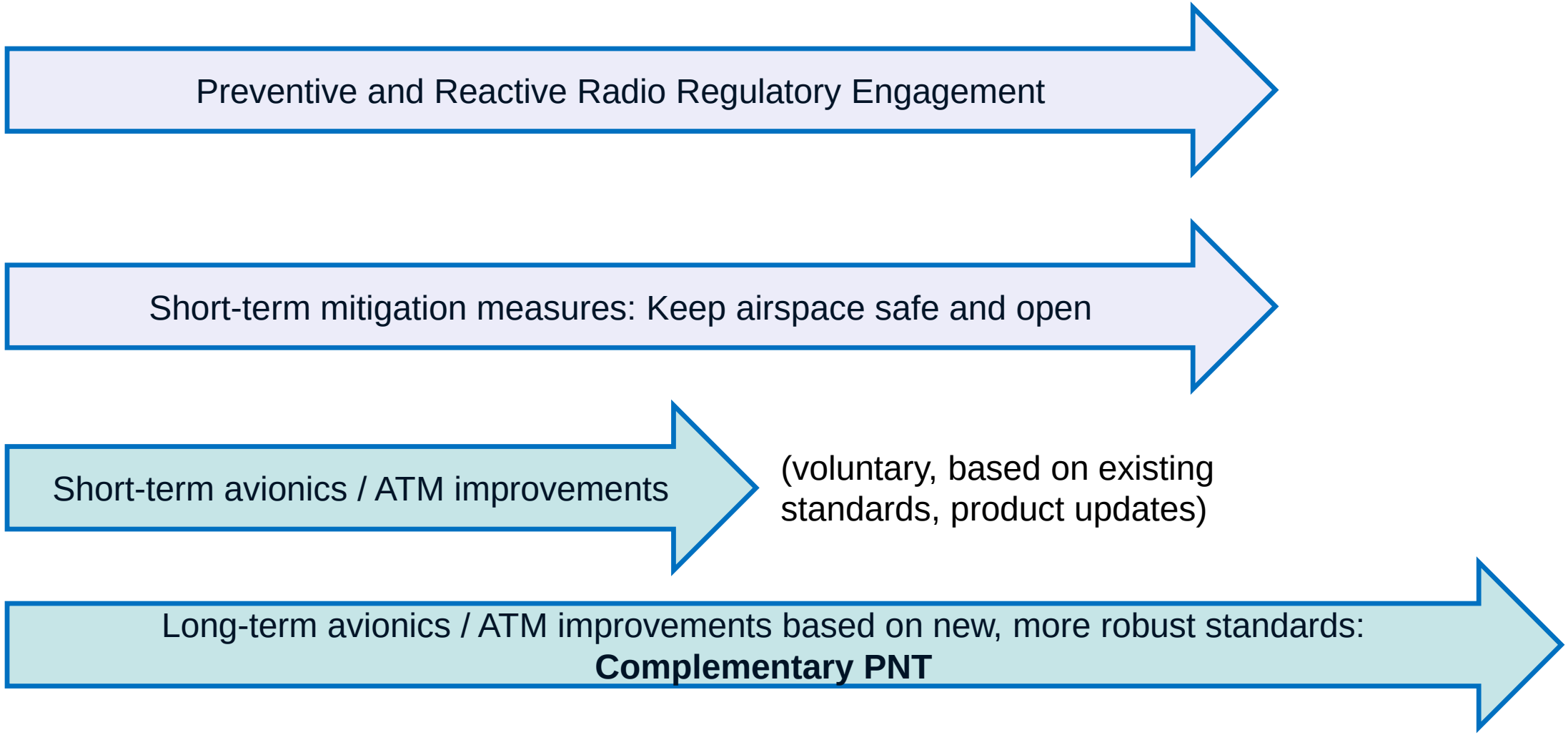


# DME Ground Transponder Integrity




Current generation DME installed in Europe typically meet 1-$10^{-7}$/h Integrity!

# GNSS RFI Mitigation Activities



# CLOSING THOUGHTS

- A lot of GNSS RFI remains in areas which do not have an obvious link to any zone of conflict
- ITU Constitution provides sovereign right to States to deny any radio service for security purposes
  - Rights come with obligations: Limit power and impact to minimum necessary!
  - Right does not extend to neighbouring State
  - Intergovernmental coordination between Telecom (Spectrum Regulator), Aviation and Defense necessary
- Experience has shown that States get active on GNSS RFI once they have events
  - Nobody can say by now that they have not been warned
  - Even occasional events (Denver & Dallas in the US) can have significant cost
  - “An ounce of prevention is worth a pound of cure”

# Further References EUROCONTROL / EASA

- GNSS RFI reporting: https://www.eurocontrol.int/service/eurocontrol-voluntary-atm-incident-reporting
- GNSS contingency procedures: https://www.eurocontrol.int/publication/european-gnss-contingency-reversion-handbook-pbn-operations
- EUROCONTROL Guideline on GNSS Interference Testing (enables coordination for those willing to coordinate) https://www.eurocontrol.int/publication/eurocontrol-guidelines-process-civil-military-gnss-interference-testing
- PBN Portal https://pbnportal.eu/epbn/home/home.html and GNSS Threat Assessment Tool https://pbnportal.eu/epbn/main/PBN-Tools/GNSS-Threat.html
- GNSS RFI Training Course https://learningzone.eurocontrol.int/ilp/pages/course-description.jsf?courseId=20758176&catalogId=896269&isTemplate=true

- EASA SIB https://ad.easa.europa.eu/ad/2022-02R3

# Further References ICAO / ITU

- ICAO GNSS Manual Doc 9849 (being updated)
- ICAO Assembly Resolution 41-8C
- ICAO EUR/MID Workshop February 2024 leading to
  - **ICAO State Letter 2024/054, Aviation safety concerns regarding interference to GNSS**
- ICAO Air Navigation Conference 14 (incl. European WP 61 and 63)
  - **Recommendation 2.2/2 – Addressing GNSS interference and contingency planning**

- ITU WRC23: Resolution 676 on RNSS (GNSS L1/E1 and L5/E5)
- ITU Circular Letter CR/488, 8 July 2022

# Further reading & watching (somewhat outdated)

- Technical Webinar on GNSS RFI: https://www.eurocontrol.int/event/eurocontrol-stakeholder-forum-gnss
- GNSS RFI risk assessment: EUROCONTROL Think Paper #9 https://www.eurocontrol.int/publication/eurocontrol-think-paper-9-radio-frequency-interference-satellite-navigation-active
- Aviation and Spoofing? https://insidegnss.com/gnss-spoofing-and-aviation-an-evolving-relationship/