ICAO GNSS RFI Mitigation Plan
and associated Eurocontrol Efforts

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Overview

• High Level ICAO Provisions

• GNSS RFI Mitigation Plan Overview
  • Principles
  • Regional and Global Support to States

• Summary of Supporting Developments Plans
  • Short, Medium & Long Term Detection Capabilities
    • “Closed Loop GNSS Service Provision”
  • Intervention Capabilities to Locate and Stop RFI Events

Note: Work supported by SESAR WP 15.1.6 Spectrum, 15.1.7 CNS & 15.3.4 GNSS plus NM
Recommendation 6/8 – Planning for mitigation of global navigation satellite system vulnerabilities

That States:

a) **assess the likelihood and effects of global navigation satellite system vulnerabilities in their airspace and apply, as necessary, recognized and available mitigation methods**;

b) **provide effective spectrum management and protection of global navigation satellite system (GNSS) frequencies to reduce the likelihood of unintentional interference or degradation of GNSS performance**;

c) **report to ICAO cases of harmful interference to global navigation satellite system that may have an impact on international civil aviation operations**;

d) **develop and enforce a strong regulatory framework governing the use of global navigation satellite system repeaters, pseudolites, spoofers and jammers**;

e) allow for realization of the full advantages of on-board mitigation techniques, particularly inertial navigation systems; and

f) where it is determined that terrestrial aids are needed as part of a mitigation strategy, give priority to retention of distance measuring equipment (DME) in support of inertial navigation system (INS)/DME or DME/DME area navigation, and of instrument landing system at selected runways.
ANSP Responsibilities: ICAO GNSS Manual (Doc 9849)

- 5.1.5 State regulators and **ANS providers can take the measures described in this chapter** to reduce the likelihood that GNSS service will be lost.
- 7.11.3.1 **ANS providers must be prepared to act when anomaly reports** from aircraft or ground-based units suggest signal interference. If an analysis concludes that interference is present, ANS providers must identify the area affected and issue an appropriate NOTAM.
- 7.12.5 **National and international coordination of actions to prevent and mitigate GNSS interference is essential.**
- 7.13.1.1 As described in Chapter 5, States can **take measures to reduce the likelihood of service outages** due to unintentional and intentional signal interference. **ANS providers must still, however, complete a risk assessment** by determining the residual likelihood of service outages and the impact of an outage on aircraft operations in specific airspace.
- **Appendix B, Roles of ANS Providers and Regulators:** **ANSP to establish appropriate strategies to mitigate GNSS outages**, Regulator to validate the safety aspects of the mitigation strategies.
Introduction to RFI Mitigation Plan

- GNSS RFI Mitigation Plan History & Context
  - Initiated by Spring 2013 Workshop at Eurocontrol Navigation Steering Group Meeting
  - Guidance developed through ICAO Navigation Systems Panel
    - In response to ICAO 12th Air Navigation Conference Job Card
  - Proposed for inclusion in GNSS Manual, ICAO DOC 9849
    - June 2016 Change Package (already used by EUR FMG)
  - Under final review by ICAO NSP Spectrum WG Correspondence Group

- Scope
  - Limited to threats requiring radio frequency propagation
  - Not dealing with corruption of position once it has left receiver
Moving from Vulnerability to Mitigation

• Objective of RFI Mitigation Plan
  • Define set of activities for States to ensure that risks to aviation from GNSS RFI are sufficiently mitigated
  • Checklists of set of activities to be considered
  • Much is already in place, State to decide depending on local environment
  • *Not intended to impose a significant workload or investment*
  • To enable reliance on GNSS and associated aviation benefits

• Focused on States
  • Spectrum a sovereign responsibility
  • Regulation and enforcement part of national oversight
  • Framework to encourage coordination and exchange of best practices
  • Supported by regional and global mechanisms due to system nature
Mitigation Plan Framework

Monitor Threats
- Proactive & Reactive Monitoring
- Environment Evolution

Assess Risks
- Scenario Variation & Escalation
- Impact Assessment
- Identify Existing Barriers

Deploy Mitigation Measures
- Reduce Risks to Acceptable Levels
- Integrate in SMS
Threat Types

- Unintentional
  - TV Broadcast Harmonics, Equipment Failure
- Intentional, not directed at aviation
  - Avoiding charges or tracking
- Intentional, directed at aviation
  - Ranges from nuisance to military threat
- Special Types
  - Military Testing
  - Spoofing

- Classification drives mitigation strategies
SPOOFING?

We don’t need to do anything, it all works, business as usual

- Aircraft Integration provides significant mitigation but situation is evolving
- Duty to close any open doors that can reasonably be closed

The world will come to an end if we ever rely on GNSS!
Risk Trade Space

- Normal Events, Limited Severity
- Unpredictable Catastrophic Event

If probability difficult to quantify, only approach is to limit impact.
Operational Risk Context

- "Loss of Nav" is an event that each aircrew needs to be prepared for at any time
  - Safety Procedures are in place
- Potential of Wide Area GNSS Outage: ATM Context
  - Especially in busy airspace, significant workload risk if many aircraft ask controller for navigation assistance
  - Very busy airspaces tend to be mainly vectored already but move to PBN should reduce this
  - NAV has multiple roles including pilot SA to manage flight
- Reversion Scenarios for PBN
  - Majority of Air Transport Users has DME/DME and INS
  - "Budapest Real Time Simulation"
  - VOR/DME does not provide suitable RNAV capability
  - PBN implementation planning
  - ICAO Annex 10 NAVAIDS Strategy
Implementing Mitigation Barriers

Prevent Transmission of RFI
- Regulatory Control and Enforcement
- Outreach

Prevent GNSS Service Outage
- GNSS Resilience
- On-board Integration

Limit Severity of Impact
- CNS/ATM Integration
- A-PNT
- Detection & Resolution

Supported by Threat Monitoring Networks (Preventive & Reactive Role)
Generic RFI Mitigation: 4 Steps

Note: applies to all RFI types & scenarios!

1. Detection of RFI
   • Ground monitoring networks (aviation & non-aviation)
   • Pilot reports: difficulty in cause-effect recognition & subsequent processing
     • Automated in-flight detection would be better?
   • Flight Inspection: continuous or on occasion (non-uniform capabilities!)
   • Determination of affected area and impact critical to launch response

2. Localization of Source: ranges from simple to extremely difficult
   • In cooperation with telecom regulator / affected non-aviation parties
   • Identification of operator

3. Termination of RFI:
   • Need clear legal basis and resources for enforcement action
   • Cross border issues can be lengthy to resolve

4. Application of Consequences: fine, publicity - future deterrent
   • Update of RFI Mitigation planning as needed
Key Starting Challenges

- Observability of RFI Events
  - Lack of reports does not mean that RFI cases don’t exist
  - Existing Spectrum Groups receive few reports
  - NOTAM search produced few results
    - Standardized terminology developed
  - Need to know what happens at aircraft!

- Confirmation of RFI Event
  - Difficult to conclude that GNSS outage is result of RFI
  - All other causes of outages are not local ANSP issue

- Both Challenges require State-external support
Identification of Probable Cause Through Elimination

Due to Constellation / Satellite?
- CSP Centers (GPS NAVCEN, etc.)
- Augmentation User Support (ESSP, etc.)

If all else can be excluded, must be RFI!
- Local Verification & Resolution

Due to Space Weather?
- Space Wx Agencies (NOAA, etc.)
- Iono Monitoring Networks

Reported GNSS Outage Event

Due to Receiver Problem?
- Receiver Manufacturers
- Avionics Integrators
- Civil-Military Coordination, NATO National Defense

Due to Military Testing?
GPS OUT Reporting Streams Today

GNSS Multi-Modal
Aviation one User among many

GPS NAVCEN

First Step: Align Aviation Coordination

Second Step: Interfaces with GNSS System Providers

IATA

EOSSP

Aviation Specific
GNSS Out One Issue among many

AO

- Airline OPS Center
- FOQA Monitoring?
- PIREP: Local AIS

Local ANSP?
- AIS to Technical Services
- Technical Services activate subsequent process?

No aggregate vision of events ➔ Incomplete threat picture
Resolution depends on awareness of many individuals
Meeting “Stated ATCO Requirement”

• Budapest GPS Outage Simulations:
  • “Tell me when event starts, when it ends, and how many sectors are affected”
  • No simple technical solutions exist today
  • Allows contingency planning through planner ATCO

• Best to monitor at the impact source: aircraft receiver
  • Currently, only pilot can observe receiver outage
  • Subsequent reporting requires support at regional and global level to determine probable cause (only RFI is local problem)
  • Provides essential risk assessment link on operational impact
Implemented: GNSS in EVAIR

- EVAIR = Eurocontrol Voluntary ATM Incident Reporting
  - Established Safety Process (Confidentiality, Anonymity)
  - 250 Participating Aircraft Operators
  - Coverage: Europe, Middle East, Northern Africa
  - Close cooperation with IATA
  - Part of Network Manager Functions

- Info Bulletin / Request sent beginning 2015
  - Initial wave of reports received covering 2013/2014
  - Additional reports coming in every few weeks
  - GNSS Outage one issue among many
  - Simple to set up because it is an existing process / framework
  - Working on further awareness materials
GPS Issues: EVAIR Findings

(Status May 2015)

- First reports received in 2013
- No of reports in the DB - 42
- No of AOs (Aircraft Operator) reporting GPS outages so far - 11
- No of locations identified – 17
- En-route flight phase most affected
GPS Issues: EVAIR Findings

Type of reported GPS issues 2013 – 2014

- Loss of GPS Signal
- GPS Outage
- GPS Jamming
- Total Loss of GPS
- GPS 1 and 2 Lost
- GPS 1 Lost
GNSS in EVAIR: Threat Monitoring

- Return to normal operations & impact on both receivers on few aircraft point to RFI with high probability
  - Proves that RFI Outages are REAL but also limited in operational impact currently

- Time-limited, single events do not warrant action
  - Supports strategic objective of threat monitoring
  - Enables setting boundaries on event probability and severity
  - Provides detection if environment changes

- Maintain central repository and statistics of GNSS Outage events
  - Consultation of GNSS service and space weather monitoring reports provide further refinement
  - May also benefit from data from local ground receivers
  - Clarify interfaces for aviation-relevant reporting
EVAIR GPS Issues Information Flow

- **EVAIR-GPS focal point**
  - Review (SAF, NAV, AOLC)
- **“GPS Group” Review & Next Step**
  - Determine probable cause through consultation with GNSS channels
  - Yes, potential issue
- **NM Coordination**
  - Heads-up to Other SH
  - Heads-up to AO’s
- **Notify ANSP(s)**
  - Inform if important
- **ECTL NM internal**
  - No issues
  - Determine probable cause through consultation with GNSS channels
  - EASA
  - No Action (await more reports)
  - No Action (await more reports)
EVAIR: Trigger for Detection & Mitigation

- Significant accumulation of events in specific area leads to detection and triggers mitigation action
- Ensuring timely resolution reduces vulnerability / exposure

Detection by EVAIR

3rd Party Reports → Inform AO’s

Local ANSP - Confirm RFI Case

Pilot / Voice Reports

Locate & Eliminate Source in cooperation with local regulatory & enforcement authorities

➢ Deploy Operational Contingency Measures
➢ Publish NOTAM if reqd.
Interfaces with GNSS System Operators (GSO)

- Currently, mainly GPS NAVCEN and ESSP
  - Multi-constellation: GLONASS, Galileo, Beidou Service Centers
  - Regional SBAS User Support Centers (GBAS with local ANSP)

- **Case 1: Strategic Long Term Threat Monitoring**
  - Info from GSO to Aviation: Ensure comprehensive view of all aviation-relevant cases

- **Case 2: Tactical Mitigation: Actual Significant Outage Event**
  - Request from Aviation to GSO: Support in identifying probable cause
  - Benefit from established links (receiver issues, ionosphere, RFI testing)
Medium Term Improvements

- Not really Pilot’s job to determine cause of GPS outage or to report signal in space issues
  - In the age of SWIM, should be automated
  - RFI detection standard feature in many commercial receivers

- CNS Idea: Reporting through ADS-B Figure of Merit
  - Part of ongoing investigations
  - Feasibility demonstration: Australia
  - Demonstrated benefit of air-ground cooperative approach
  - Need to test and build experience in how to integrate information

- Some guessing remains with respect to probable cause
  - Especially for wide-area outage where resolution should be fast
  - Serendipitous capability, but not ideal
ADS-B PIC Use for GNSS Monitoring

- **ADS-B:**
  - Different versions of the ADS-B Out MOPS in use
  - Different ways to encode integrity
  - Not all aircraft are “proper” ADS-B Out:
    - Version 0 implemented on voluntary basis (along with Mode S mandates, ADS-B only certified on a non-interference basis)
    - Later AMC 20-24 certification only applies to subset of fleet
    - Not necessarily using GNSS as position source
    - Some known avionics issues with version 0

- **GNSS:**
  - Different levels of performance
    - Limited information about the position source (SA On/Off, SBAS etc.)
ADS-B based GNSS Monitoring: Issues

• Difficult Capability to Test without significant RFI Event
  • Study tried to correlate ADS-B Position Integrity Category with events:
    • Known RFI Events
    • Predicted RAIM Outages
    • Iono Events
    • None of the investigated events produced reliable correlation

• But learned about use of ADS-B data
  • Careful filtering of reliable data – establish white list?
  • On-board issues usually result in a certain NUCp/NIC behaviour
    • not so common – can be filtered out
  • Most of the fleet has stable quality indicators
  • SPI IR implementation of ADS-B Out version 2 (ED-102A / DO-260B) expected to further improve the picture

• Still think that method has promise at least for “massive” RFI events
Long Term RFI Mitigation Improvements

• A lot can be done with current capabilities at reasonable cost
  • EVAIR is available now
    • *Mostly a matter of setting up interfaces and data integration*
  • ADS-B FOM Monitoring excellent example of CNS synergy use without introducing additional complexity
    • Still want to reduce guesswork in future equipment

• Next Generation MC GNSS Avionics
  • ICAO NSP requested implementation of reasonable mitigation capabilities from RTCA / EUROCAE
    • Must be careful to not impact continuity of service
  • Detection capability seen as a feasible minimum
    • Permit aircraft to switch to “A-PNT capability”

• Information must reach ANSP
  • Quick Access Recorder, Flight Operations Quality Monitoring
  • Future: SUR Downlink Aircraft Parameters (DAP) ??
RFI Localization Developments

- Controlled Radiation Pattern Antennas CRPA
  - Multi-element GNSS antenna used in defence applications
  - Not an option for airliners, but maybe flight inspection aircraft?
  - Cooperative project with FAA and DSNA

- Project Goals
  - Develop and Demonstrate Concept & Feasibility
  - Increase localization antenna sensitivity
  - Maintain own-ship position during RFI

- Process
  - Directly obtain pointing to RFI source with reduced search time
  - Allow efficient deployment of ground capabilities
  - Reduce vulnerability by dramatically reducing intervention time
Summary

ICAO GNSS RFI Mitigation Plan
- Mature and available to States
- Hope to learn from feedback from local implementation

Regional and Global Support Process being put in place
- EVAIR Data and Network Manager Process
- Continuing work on appropriate airborne monitoring capabilities
- Continuing work on increased intervention capabilities
- ATCO training can mitigate until next generation capabilities in place

A lot can be done with relatively simple means
- So far, GNSS RFI threats have not lead to significant risks to aviation operations
- Continued cooperation and development of RFI vulnerability mitigation capabilities can ensure that this remains the case
- To enable full exploitation of Operational PBN Benefits
Back-Up

- Sydney Case to confirm utility of ADS-B monitoring to narrow search area
- Position Integrity Category Table
Sydney Case: ADS-B Lessons Learned

• ADS-B reports key to identifying probable source location: Aerospace Industrial Park
  • “Search” proved sufficient to terminate 3h event
• Most Ground Monitor Stations didn’t see RFI
  • Some outages on WAM network, but difficult to locate
  • Need to evaluate line of sight

• Lessons Learned
  • Aircraft with INS didn’t lose NAV
  • Contingency procedures worked
  • Some aircraft GPS receivers didn’t recover (even on turnaround!)
  • Air Services Australia recommends recording of GPS status on QAR
  • Ground and aircraft based localization must work in complement
  • Implementation simplest if within existing processes & infrastructure
### Position Integrity Category

- Ground system notation (Asterix) for integrity containment bound encoding

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