GNSS RFI Source Localization using Flight Track Data

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Overview

• Detecting GNSS Outages
  • From passive threat monitoring to active intervention in case of relevant events

• Determination of Probable Cause
  • Elimination of Non-RFI Causes

• Localization and Elimination of RFI Source
  • Supporting the chain of detection (Operator / ANSP) to confirmation, characterization and localization (radio regulator) to elimination (law enforcement)
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

GNSS RFI Vulnerability

Note: Limiting “success probability” of intentional RFI limits likelihood of events (exposure to detection)

Supported by Threat Monitoring Networks (Preventive & Reactive Role)
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
  - Try to get as much information from the air as possible before starting search on ground: *cooperative approach for efficiency*

ATCO = Air Traffic Control Officer
GPS OUT Reporting Streams Today

GNSS Multi-Modal
Aviation one User among many

Aviation Specific
GNSS Out One Issue among many

GPS NAVCEN ➢ Airline OPS Center
➢ FOQA Monitoring?
➢ PIREP: Local AIS

ESSP ➢ AIS to Technical Services
➢ Technical Services activate subsequent process?

Local ANSP ?

IATA ➢ Eurocontrol Network Manager

No aggregate vision of events ➔ Incomplete threat picture
Resolution depends on awareness of many individuals
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 sent beginning 2015 and mid-2016
  • 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
  • Sending further awareness materials to aircraft operators
GPS Outages - Phases of flights
2013-2016

ENR 93%

GND 1%

TOF 1%

APP 5%

APP/LND 0%
B777 is most flown type in areas most affected

Most Events Occur at Night!
Specific Actions already facilitated by EVAIR:
- *Information Bulletin* sent to Airspace Operators in Black Sea / Caspian Sea Region
- NOTAM Issued by Turkey’s DHMI (Ankara Region)
Geographic Distribution of Events
(as of SEP 2016)

ECAC = European Civil Aviation Conference
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 ?
Moving Towards RFI Localization Support

• Primary current method to detect potential RFI is pilot reporting
  • Pilot reporting by nature not precise about location of event
  • Developing process of what to do with reports
  • Evaluating if meaningful localization can be made possible if flight track data is made available

• Prerequisite is that relatively precise lat/lon/ht of GNSS Outage event start and end is available
  • Either through ADS-B or other airline data reporting system
  • Possible for single, omnidirectional and static RFI source only
    • If search inconclusive using this method, could also be a valuable data point to suspect more sophisticated threat

• Objective is to reduce RFI source search area for State and reduce associated intervention time
Flight Track Data Possibilities?

- If precise report of start and stop coordinate of outage event are known, bisector line of potential RFI source location can be derived
  - Assumes omnidirectional RFI source and constant aircraft altitude
  - Assumes that loss of tracking and reacquisition thresholds are similar
  - Multiple aircraft reports could lead to localization
- Within limits, a minimum power level can also be hypothesized
Modelling and Visualisation in DEMETER

- GPS track 1 (eastbound)
- GPS track 2 (southbound)
- Possible RFI position
Figure removed. Work ongoing to obtain agreement from ANSP to show location of outages.
[ Confidentiality vs. Anonimity: Position Data is never anonymous ]

Actual cases will always be coordinated with the ANSP responsible for the affected airspace.
FlightAware Coverage
FlightAware Coverage
RFI Localization Process

• EVAIR Reports serve as a trigger for further investigation
  • First check to eliminate non-RFI causes as much as possible
• Then need to rely on public domain ADS-B sources
  • Manage coverage and data quality issues
  • Limitations on data history
  • Limitations on track distribution (due to route network)
  • Recall earlier findings (CNS Team, Avionics White List)
• Options to be investigated:
  • Framework agreement with ADS-B data providers?
  • Publication on Network Manager Operations Portal Nconnect
  • Further investigation of aircraft installed GNSS Rx tracking and acquisition thresholds as a function of ground based RFI type and main airframe type?
  • Future Alternatives: GNSS RX Data, Global Flight Tracking?
Summary

- GNSS RFI Mitigation continues to be an exercise in setting up interfaces
  - Current effort on ADS-B track data providers
  - Other venues to be developed: GNSS providers, multi-modal projects (EC), Aircraft OEM’s, Airline FOQA Systems, NATO?
  - Developing “GNSS Information Concept” to know what to make available to aircrews and how (NOTAM or alternate channels)
  - *Happy to consider any data source incl. ground monitors!*

- Focus on short-term implementable options that approach stated ATCO requirement (“tell me which sectors are affected”)

- AOB: Related IFIS and ION Paper: RFI Localization using CRPA
  - Published in GPS World Magazine
  
Requests to UN ICG IDM Workshop

• Support information exchange for aviation with GNSS system operators
  • For both threat monitoring and significant event mitigation
  • Help to identify non-RFI causes (space weather, receiver issues if aware)

• Forward aviation relevant reports to relevant entities (States, Regional Organizations)
Back-Ups

- ADS-B Details
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
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
Position Integrity Category

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

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