Flight Inspection Developments and Challenges

Gerhard Berz
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Current ICAO NSP Developments on Flight Inspection

- ICAO Annex 10, Vol I, Chapter 2, Section 2.2.1: “Radio navigation aids of the types covered by the specifications in Chapter 3 and available for use by aircraft engaged in international air navigation shall be the subject of **periodic ground and flight tests**.”

- Vol I update published in 2018
  - Opened door to use of drones with mention in one paragraph in chapter 1
    - Interest in use of drones for flight inspection has increased significantly since then
  - COVID challenges
    - Updated paragraph on return to service
  - No specific schedule yet for another update
Reduced Flight Inspection (mainly for ILS)

- Current Doc 8071 V1 only speaks about flight inspection periodicity
  - Guidance discusses conditions for extending nominal intervals
  - No guidance on reducing the number of flight inspection runs
  - Current example report has 17 runs, some States use up to 20 – 30 runs
  - Modern ILS systems have become much more stable

- Some states have significantly reduced the number of ILS flight inspection runs
  - In some cases justified based on improved measurements through use of drones
  - Other methods including modelling and environment control also possible
  - Doing less runs at nominal intervals can provide better control of signal environment
  - Main current focus are small drones as a ground maintenance tool

2nd Generation UFIS used by China
## ILS Glide Path Testing

### Domains of Applicability depending on Test Method

<table>
<thead>
<tr>
<th>Changes in:</th>
<th>&quot;Blind&quot; monitoring methods (no Signal in Space)</th>
<th>Nearfield area</th>
<th>Farfield area</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Integral MONs</td>
<td>Tilt Sensor</td>
<td>NF MON</td>
</tr>
<tr>
<td>GP antenna signal output</td>
<td>detected</td>
<td>not detected</td>
<td>detected</td>
</tr>
<tr>
<td>GP antenna geometry</td>
<td>not detected</td>
<td>partially detected (only mast tilt)</td>
<td>partially detected</td>
</tr>
<tr>
<td>GP signal in space</td>
<td>Beam Forming Area</td>
<td>not detected</td>
<td>not detected</td>
</tr>
<tr>
<td>External disturbances</td>
<td>not detected</td>
<td>not detected</td>
<td>detected</td>
</tr>
<tr>
<td>GP signal in space over the RWY</td>
<td>from GP to NF MON</td>
<td>Beam Forming Area</td>
<td>not detected</td>
</tr>
<tr>
<td>External disturbances</td>
<td>not detected</td>
<td>not detected</td>
<td>detected</td>
</tr>
<tr>
<td>GP signal in space in short final</td>
<td>from THR to 1.5 km THR</td>
<td>Beam Forming Area</td>
<td>not detected</td>
</tr>
<tr>
<td>External disturbances</td>
<td>not detected</td>
<td>not detected</td>
<td>not detected</td>
</tr>
<tr>
<td>GP signal in space in the whole service volume</td>
<td>from 1.5 km THR to 10 NM THR</td>
<td>External disturbances</td>
<td>not detected</td>
</tr>
</tbody>
</table>

**Notes:**
- ILS Glide Path Testing
- Domains of Applicability depending on Test Method
- Changes in:
  - GP antenna signal output
  - GP antenna geometry
  - GP signal in space
  - GP signal in space over the RWY
  - GP signal in space in short final
  - GP signal in space in the whole service volume
- "Blind" monitoring methods (no Signal in Space):
  - Integral MONs
  - Tilt Sensor
  - NF MON
- Nearfield area:
  - Ground Check at THR
- Farfield area:
  - Drone Check at 1.5 km THR
  - Very close to Farfield
  - Flight Check

**Image Notes:**
- Diagram showing ILS Glide Path Testing with key visual elements:
  - 80 m, 300 m, 1.5 km, and 1.5 km THR dimensions
  - Flight Check at 1.5 km THR
  - GP signal in space over the RWY
  - External disturbances
  - GP antenna signal output
  - GP antenna geometry

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Reduced ILS Flight Inspection – work in progress

- Small measurement drones can fly more precise at slower speeds
  - Provides much better sampling of Signal in Space
- Especially for Glide Path, far field measurements provide significantly better measurements than a mast measurement
  - Glide path mast measurement can be misleading – only a consistency spot check
- Drone measurements can be a very suitable tool to justify reduction of flight inspection runs
  - Reduces ILS operation and maintenance cost
- Drones for complete flight inspection are also gaining momentum
- Retaining ILS expertise is becoming a significant challenge
Update of Volume 2 on GNSS (ongoing)

- With removal of flight validation, GNSS Volume is becoming thin
  - Material moved to Doc 9906 V5 under responsibility of Instrument Flight Procedures Panel
  - GNSS Signal in Space analysis is best done with data collection receivers (or network of receivers) on ground
  - Nature of “testing” evolving toward engineering data analysis
  - Main content in terms of size will be GBAS
  - Maintaining two volumes to minimize editorial efforts

- Sometimes boundary between flight inspection and flight validation can be argued
  - In particular with landing systems reference path as it is the reference for guidance signals
  - Improved guidance on flight path alignment verification
Volume 2 Revised Structure

1. General: GNSS-specifics only, no more duplication of chapter 1 in Vol I

2. ABAS for NPA becomes GNSS Core Constellations and ABAS
   • Link to new material in Doc 9849, GNSS Manual, on Performance Monitoring

3. SBAS: Testing relevant to SBAS service provider, TBD?

4. GBAS: Most significant update including GAST D

5. Flight Validation becomes new GNSS RFI measurement chapter
   • Building on attachment 3 to chapter 1
Coping with GNSS RFI in Flight Inspection

- Differential GPS has been the system of choice for high accuracy airport flight inspection reference systems
  - In some cases, necessary to revert to use of Inertial with camera update and/or theodolites
  - New option in interference free environments: Galileo High Accuracy Service (HAS)
  - Using more robust GNSS systems should also be considered: CRPA

**Controlled Radiation Pattern Antennas:** more feasible for special mission aircraft?
- More robust GNSS
- Could help to geolocalize RFI Sources

![Controlled Radiation Pattern Antennas](image)

Aircraft bottom mounted direction-finding array (multiple frequency bands), French Flight Inspection

**Improving In-Flight Localization of GNSS RFI Sources**

Gerhard Bierz, Pascal Barret, EUROCONTROL
Michael Richard, Brent Dissekoien; Rockwell Collins
Todd Bingham; FAA
Vincent RoCchia, Florence JACOLOT; DNSA/DTI
Oikko Bleeker; OFBleeker Consult

ION GNSS+
Portland, 12 – 16 September 2016
Use of CRPA for In-flight RFI Source Localization?

Proposed Principle of Operations

- **Rockwell Collins DIGAR: Digital GNSS Anti-jam Receiver**
- **Algorithms able to detect wide range of RFI sources (Continuous Wave (CW), swept CW, Broadband, …)**
- **AHRS and Direct Geolocation Processing NOT YET implemented / investigated**

Installed system includes:

- **CRPA**
- **Antenna & interface cabling**
- **DIGAR with GNSS Baseband Processing**
- **Laptop with DF Software**

Jammer Direction Finder Display

- **White area: possible RFI direction**
- **Red dot: received power above specified threshold**

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DLR Research on Small CRPAs

Is Size the Limiting Factor?.. No!

Images: Novatel, Antcom, DLR

Antenna and processing unit for flight tests 2022

Fighting Spoofing starts with good Threat Data!

- EUROCONTROL proposing to equip *some* aircraft which operate in hotspots with a data recording platform
  - Anything else is guesswork (pilot reports & currently available aircraft data)
  - Flight Inspection aircraft would be ideal for this
  - *GNSS Receiver Manufacturers are looking for test data for system development*
- Approach: use GNSS observables to trigger suspected spoofing event
  - Trigger activates RF signal I/Q recording – to avoid excessive amounts of data
  - Suitable experts need to be available to analyse the data
  - ONLY way to build a realistic risk assessment – proven experience with jamming
- **Could potentially include some type of pilot alert function? (or development of it)**
Summary

- We still need conventional navigation aids
  - ILS remains the most common precision approach landing system
  - ILS is more robust to spoofing than some may assume
  - ILS is fully immune to “collateral attacks” seen in GNSS
  - Modern tools including drones will help to increase ILS safety while reducing operations cost

- ICAO Doc 8071 Volume 2 on GNSS being updated
  - Will include new, dedicated chapter on GNSS RFI
  - Flight inspection capabilities to geolocate interference sources highly desirable
  - Complementary truth reference capabilities still need to be available

- Flight Inspection / Special Mission Aircraft could play a key role in understanding evolving GNSS spoofing threat to civil aviation
  - Risk mitigation requires understanding about what is going on at the signal in space level
  - Would need to set up a suitable data sharing & analysis framework