Supporting
European
Aviation

EUROCONTROL

Flight Inspection Developments and Challenges

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FOUNDING MEMBER SESAR JOINT UNDERTAKING

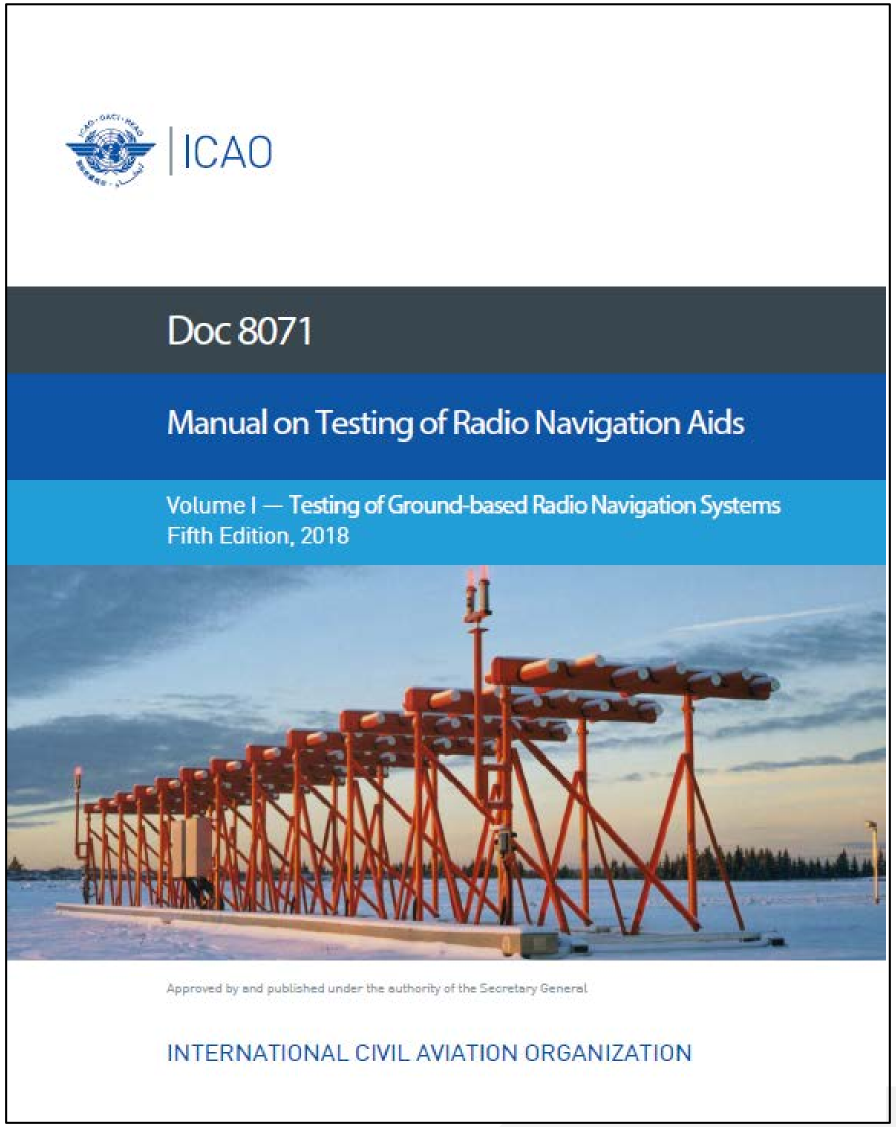
NETWORK MANAGER

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

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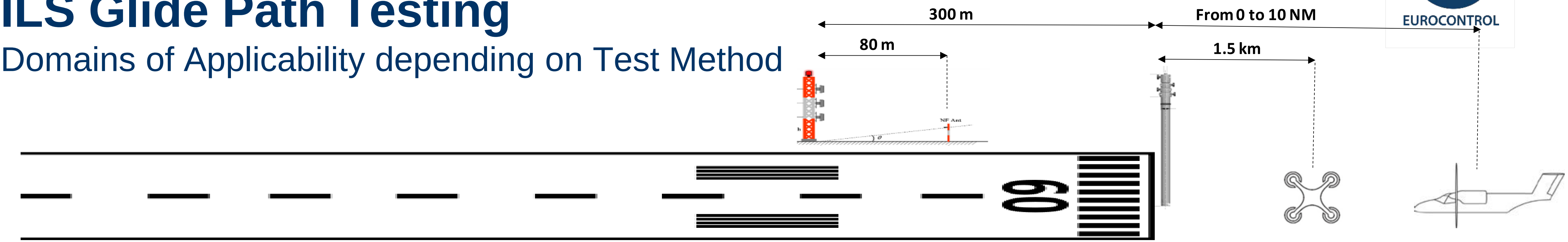


Changes in:						"Blind" monitoring methods (no Signal in Space)		Nearfield area		Farfield area	
						Integral MONs	Tilt Sensor	NF MON	Ground Check at THR	Drone Check at 1.5 km THR very close to Farfield	Flight Check
GP antenna signal output						detected	not detected	detected	detected	detected	detected
GP antenna geometry						not detected	partially detected (only mast tilt)	partially detected	**partially detected (not all cases)**	**detected**	detected
GP signal in space	from	GP	to	NF MON	Beam Forming Area	not detected	not detected	detected	detected	detected	detected
					External disturbances	not detected	not detected	detected	detected	detected	detected
GP signal in space over the RWY	from	NF MON	to	THR	Beam Forming Area	not detected	not detected	not detected	detected	detected	detected
					External disturbances	not detected	not detected	not detected	detected	detected	detected
GP signal in space in short final	from	THR	to	1.5 km THR	Beam Forming Area	not detected	not detected	not detected	**not detected (BFA extends further than the THR)**	**detected (BFA shorter than 1.5 km THR, all BFA cases covered)**	**detected (BFA shorter than 1.5 km THR, all BFAcases covered)**
					External disturbances	not detected	not detected	not detected	**not detected**	**detected**	detected
GP signal in space in the whole service volume	from	1.5 km THR	to	10 NM THR	External disturbances	not detected	not detected	not detected	not detected	not (yet) detected. Detected in the mid-future with longer approaches or further start point	detected

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

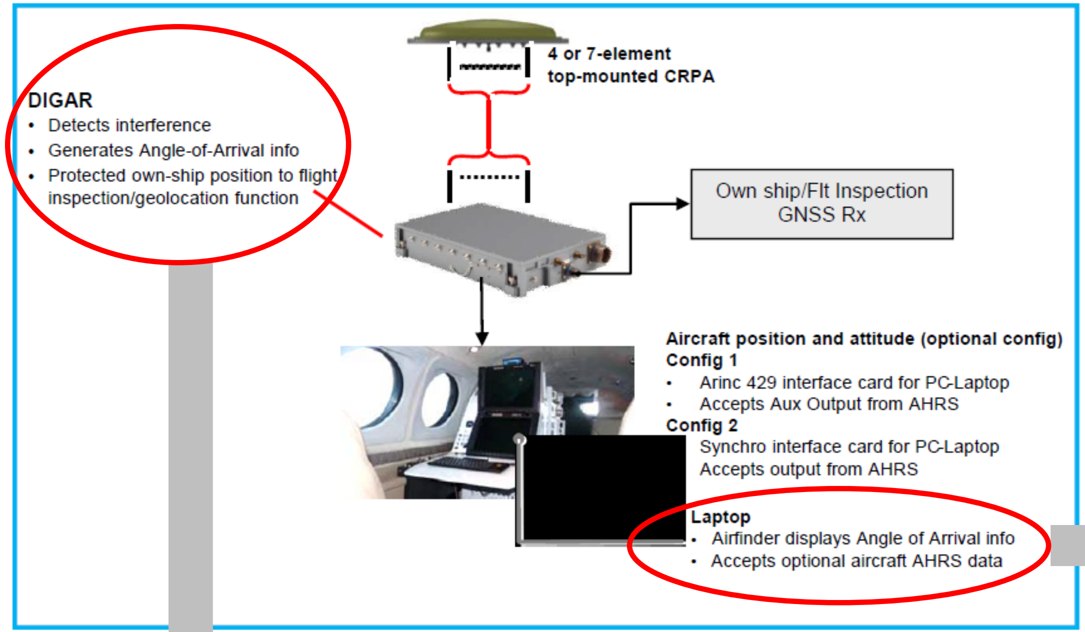
Controlled **R**adiation **P**attern **A**ntennas: more feasible for special mission aircraft?

➔ More robust GNSS

➔ Could help to geolocalize RFI Sources

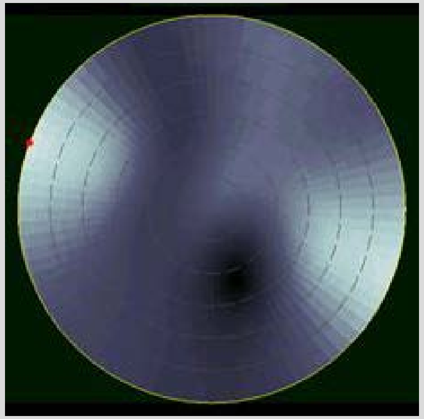
Aircraft bottom mounted direction-finding array (multiple frequency bands), French Flight Inspection

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

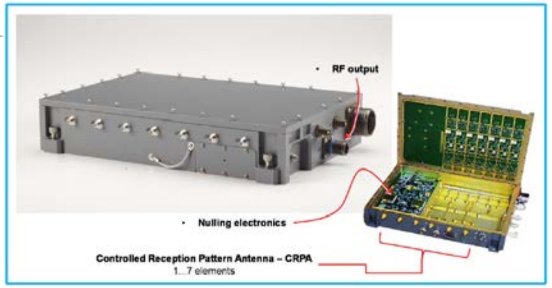


- **White area: possible RFI direction**
- **Red dot: received power above specified threshold**

Jammer Direction Finder Display

Installed system includes:

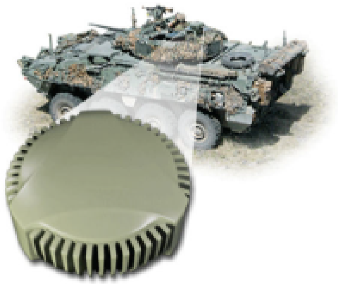
- CRPA
- Antenna & interface cabling
- DIGAR with GNSS Baseband Processing
- Laptop with DF Software

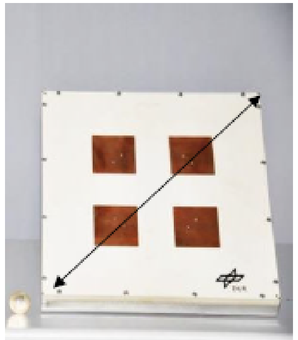


DIGAR

DLR Research on Small CRPAs

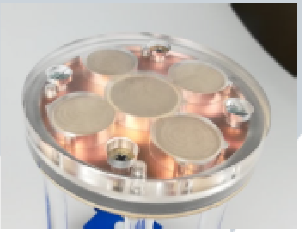
Is Size the Limiting Factor?.. No!





>35 cm
L1+L5
2011

Antenna and processing unit
for flight tests 2022



9 cm
L1+E5/L2/E6
2018

9 cm

[1] S. Caizzone et al., "A Miniaturized Multiband Antenna Array for Robust Navigation in Aerial Applications", Sensors 2019, 19, p. 2258 and Patent DE102018203191A1
[2] E. Perez Marcos et al., „CRPA and Array Receivers for Civil GNSS Applications", Proc. IEEE/ION PLANS, 2023

Images: Novatel, Antcom, DLR

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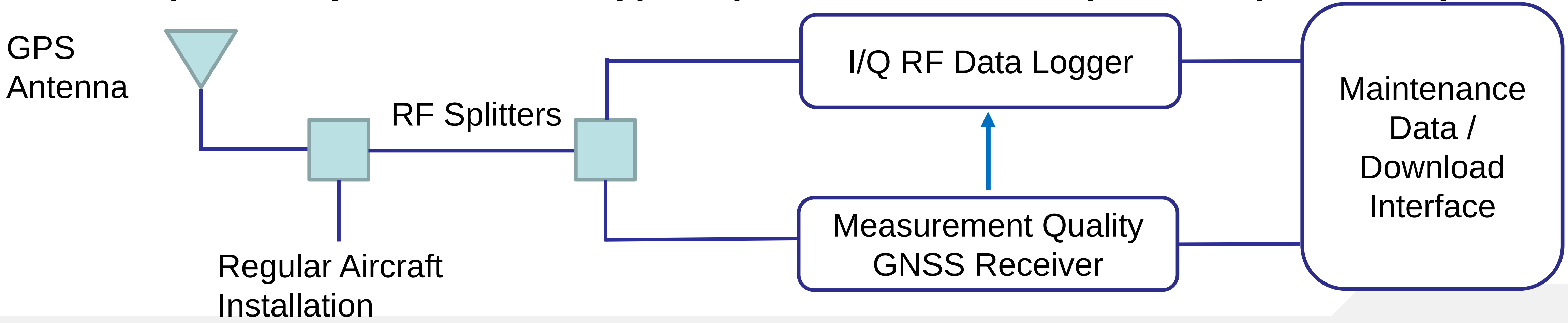
Fighting Spoofing starts with good Threat Data!

- 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