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ICAO Provisions and Guidance on Flight Inspection

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FOUNDING MEMBER SESAR JOINT UNDERTAKING

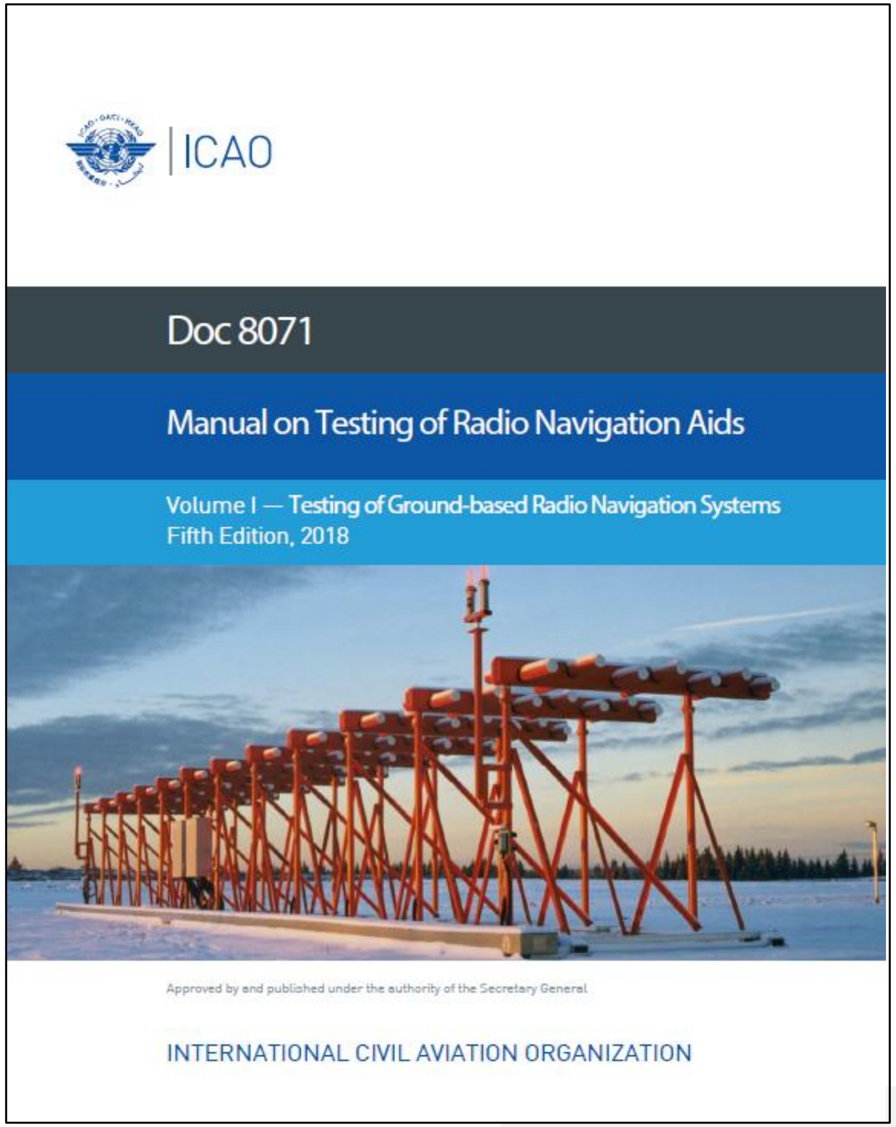
NETWORK MANAGER

Testing of Ground Based Radio Navigation Systems
(Doc 8071 Volume I)

- 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****.”*

- Note refers to Doc 8071 to explain how it can be done, based on **best practices established in some States experienced with the provision of radio navigation aid services**
- **To ensure continued compliance to Annex 10 during operational service life in installed environment**
- NOT meant for design assurance testing



ICAO NSP Activities Related to DOC 8071

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- Volume I: Testing of Ground Based Navigation Systems
  - Currently 5th Edition, 2018
    - Updated to align with Annex 10 revision (Amendment 84)
    - Only one paragraph “open door” for drone flight inspection
    - NSP still sees ALL drone measurements as complementary to classical flight inspection
  - **JUST FINALIZED** (going to Secretariat for ICAO-internal processing): Guidance on Reduction of Flight Inspection Volume (number of flight inspection runs, mainly ILS)
  - **ALSO** new paragraph on returning facilities to service after removal due to expired intervals (COVID)
- Volume II: Testing of GNSS
  - Update ONGOING, completion planned in 2025
  - Moved all flight validation material to DOC 9906 Volume 5 (IFPP responsibility)
  - **New chapter on GNSS RFI**
- AGREED to develop **new JOB CARD** for UAV-based Flight Inspection
  - Exact placement of material TBD, time scale TBD
  - Will cover both VLOS and BVLOS

Current Normal Flight Inspection Periodicities

Facility	Established Periodicity	Remarks
VOR	Nominally 12 Months	In some States up to 5 years for Doppler VOR
DME	Typically Annually	
ILS	Nominally 180 Days	LOC, GP, MB/DME
NDB & ENR MB	Typically Annually	Or with associated aid, such as Locator
PAR	Nominally 270 Days	

➔ *Provided as Note to "P" Entry in Flight Inspection Summary Table*

➔ *VOR & DME used for PBN: In line with facility chapters*

Reduced Flight Inspection (mainly for ILS)

- **Modern ILS systems have become much more stable**
  - With good maintenance and environmental control, flight check often is fully OK
  - DOC 8071 “Best Practices” are evolving
- Current Doc 8071 V1 only speaks about flight inspection periodicity
  - Chapter 1.15 discusses conditions for extending nominal intervals
  - Added guidance on reducing the number of flight inspection runs (new chapter 1.16)
  - Current ILS example report has 17 runs, some States use up to 20 – 30 runs
  - Doing less runs at nominal intervals can provide better control of signal environment
  - Combining period extension and run reduction needs to be done very carefully
- Updated Guidance plus 4 State Examples
  - Australia, Canada, Netherlands, Switzerland
  - One State example uses VLOS drones
  - Improved maintenance monitoring and trend analysis

Reduced Flight Inspection: Conditions / Enablers

a) demonstration of **good correlation** between the different measurement methods;

b) applying multiple and **more stringent tolerances** for flight and/or ground testing results to address uncertainties;

c) the facility is adequately **safeguarded against changes in the operational environment**, e.g. temporary objects, permanent building development or vegetation growth;

d) evidence that for a given system design, the quality of the maintenance and the **stability** of the systems concerned is as required and that the recorded test results and **monitor readings of critical parameters** indicate that the equipment consistently meets performance requirements;

e) all modifications are carefully prepared by thorough research, extensive testing and analysis, implemented step-by-step and justified with **comprehensive safety risk assessments**.

Why Conduct Periodic Flight Inspection?

“Never touch a running system: this actually has proven wrong. Legacy systems may still hide unexpected problems behind decades of undoubted operation.”

- S. Jageniak, Aerodata, Traps and Pitfalls Reloaded”, IFIS 2024, Nagoya

- Ground Maintenance in accordance with DOC 8071 and manufacturer recommendation as well as site safeguarding (ICAO EUR DOC 015) is essential for reliable operation of the system
- However, *some system faults (especially antenna systems) and some propagation issues can ONLY be discovered with flight inspection!*
- ANSP must ensure that Signal-in-Space Tolerances as per Annex 10 are maintained
    - All 8071 tests link to Annex 10 Volume I requirements

Integrity Concept for Terrestrial Navigation Aids

- GNSS Integrity is achieved **at the user level**
  - Aircraft receiver protection level calculation includes error models and overbounds for all error sources
- Terrestrial Navigation Aids provide integrity at the transmitter output to a fault free antenna system
  - Integral antenna monitors can detect many antenna faults, BUT NOT ALL OF THEM
  - Transmitter monitors provide an excellent integrity CONTRIBUTION
- **Main enemy of navaid integrity: MULTIPATH** and other propagation issues
- From ILS Critical and Sensitive Area Guidance (Annex 10, Vol I, Attachment C, 2.1.9.6):

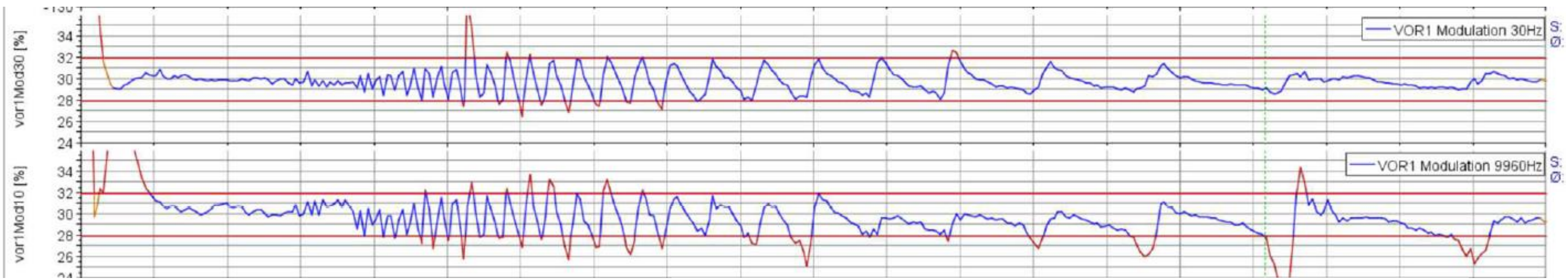
$$\sqrt{(3\mu A)^2 + (4\mu A)^2} = 5\mu A$$

Static Disturbances (as established by FI measurements!)

Dynamic Disturbances (available error budget for aircraft movements)

Multipath Examples from Operational NAVAIDS

VOR



- Especially NAVAIDs supporting Terminal Area and En-Route Service are subject to LARGE Multipath Geometries, which can ONLY be detected with flight inspection aircraft
- VOR: Wind Turbines?

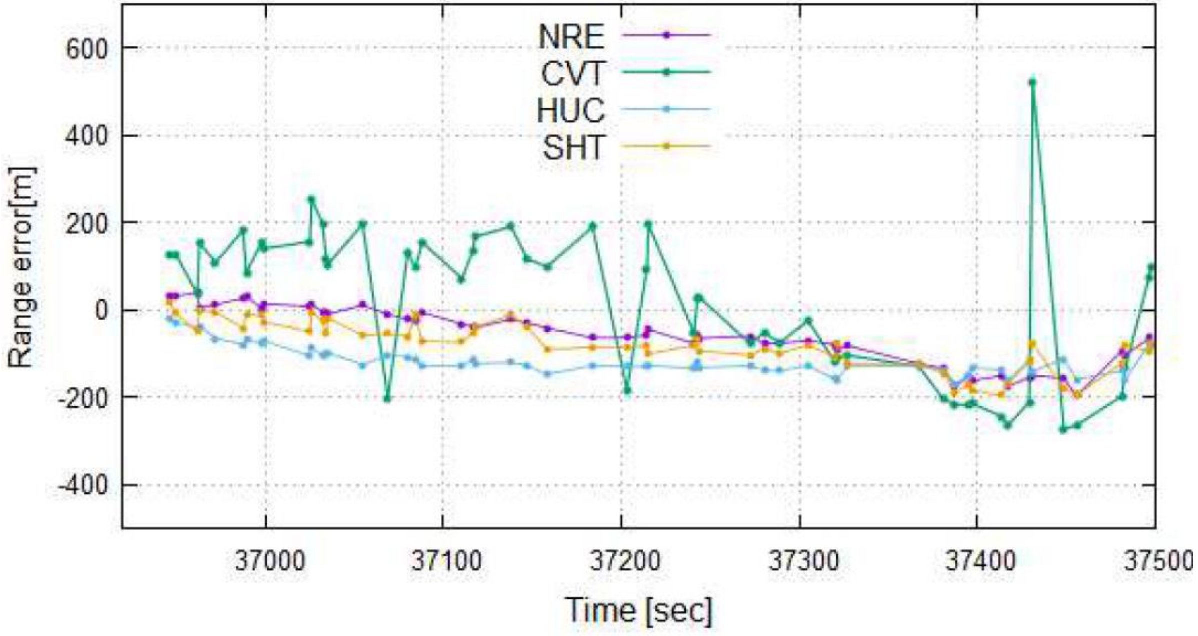
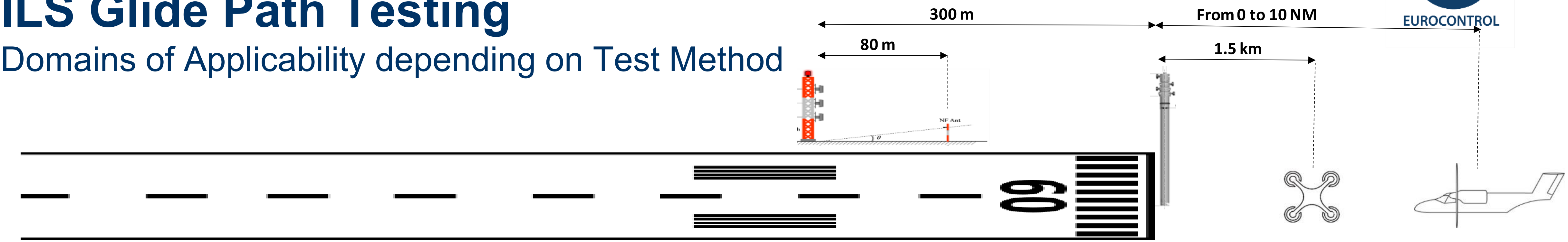


Figure 11 Distance error of each station

DME (A. Kezuka, Multi DME Japan, IFIS 2024

ILS Glide Path Testing

Domains of Applicability depending on Test Method



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

ILS Glide Path Antenna Fault: Limitation of Mast

NSP JWG10 WP24 by Switzerland

Ground Measurements @THR					Delta and ratio	
	Normal condition		Abnormal condition			
Displacement error @3.7°	**-34.4**	**uA**	**-33.5**	**uA**	**0.9**	**uA**
Total width +/- 75 uA	**116.3**	**uA**	**117.1**	**uA**	**101%**	
Drone Check at 1.5 km from THR					Delta and ratio	
	Normal condition		Abnormal condition			
Displacement error @3.7°	**-5**	**uA**	**-40**	**uA**	**-35**	**uA**
Total width +/- 75 uA	**150.7**	**uA**	**169**	**uA**	**112%**	
Flight Check					Delta and ratio	
	Normal condition		Abnormal condition			
Displacement error @3.7°	**-2.8**	**uA**	**-39.4**	**uA**	**-36.6**	**uA**
Total width +/- 75 uA	**149.9**	**uA**	**176.6**	**uA**	**118%**	

- Simulation and measurement for a standard 3 element Image Glideslope
  - Antenna system fault which can't be detected with a GP mast measurement
  - Signal in space is FULLY out of tolerance: GP displacement shifted LOW by 35μA
- *Actual fault: Element A3 turned by 2.5° in Azimuth and A2 shifted low by 18cm*

Human Element in NAVAID Integrity

- By contrast: Baro VNAV Approach: Pilot has to set correct QNH with EACH Approach
  - Significantly higher chances of error
- ILS (and to some extent VOR / DME)
  - Maintenance practices must ensure that facility is returned to operational service correctly
  - ILS Critical and Sensitive Area Protections must be effective to prevent out of tolerance multipath from dynamic objects
  - Flight checks can detect antenna faults and propagation issues
    - Requires solid antenna fixtures which resist environmental influences
    - Nearby building or other activities are controlled
    - Vegetation growth: normally slow and gradual
  - **ONLY solid engineering, maintenance and flight checks can guarantee sufficient freedom from out of tolerance guidance**
    - **Any relaxation only possible after gaining significant experience**

What Everyone is Waiting For: UAS in Flight Inspection

- **VLOS: Visual Line of Sight Operations**
- Typically 25kg Class Multi-Copter Drones
- On or NEAR Airport Perimeter
- Can be seen as an additional tool for more effective ground maintenance
- Better sampling of signal in space than a traditional FI aircraft
- Highly accurate trajectory control including areas where normal FI aircraft can’t fly
  - Establish full in-service antenna pattern
- Starting to be well-established by some ANSP, especially for ILS
- Operational safety case is easier
- More limited by weather, esp. wind
- Simpler antenna gain pattern calibration

- **Beyond VLOS (BVLOS)**
- Typically 150kg Class Fixed Wing Drone
- Can fly complete standard FI trajectories
- Needs operation as RPAS
- Build up of experience going on
- Still seen as a *COMPLEMENT* to regular flight inspection
  - Especially for demanding environments

PRIMOCO UAV
Testing in Iceland

Evolution of Flight Inspection

- Today's Flight Inspection has evolved to also cover Flight Validation
  - Requires suitable aircraft, typically with FMS and other standard avionics
  - Aircraft are capable to also check signal in space at the same time
  - Need to maintain flight inspection experience even with less runs
  - Need to preserve operational readiness if there are facility issues

- China is one of the pioneers in promoting the use of larger BVLOS UAS for FI
  - Used to conduct ILS GP LOW Clearance
  - Especially at high altitude airports
  - *Logistic and cost effectiveness can vary significantly between States*
  - **Small VLOS Drones have shown: best approach is if the community experienced in flight inspection develops their tools**

2nd Generation UFIS used by China

Incremental Approach from VLOS to BVLOS

- Technology and operational procedures becoming well established for small multi-copter drones
- “Mini Approaches” are flown in ILS far field, only takes a few minutes
  - Reduces airspace utilization time
  - Can easily be done at night
  - Requires reliable datalinks and equipment
- Multiple providers available, including drone payloads
  - Capabilities extending to VOR & DME

Basis for Application Remains the Same: Good Correlation! (Aircraft – UAS – Ground)

Expert Engineering Judgement will remain necessary

: Correlation between flight (in blue) and drone check (in green and pink) for a LOC Linearity Coverage

(“CNS Drone SkyRF Measurement System Maturity, Evolution Ongoing”, H. Demule, IFIS 2024, Nagoya, Japan)

GNSS RFI: A New Challenge for ILS Flight Inspection

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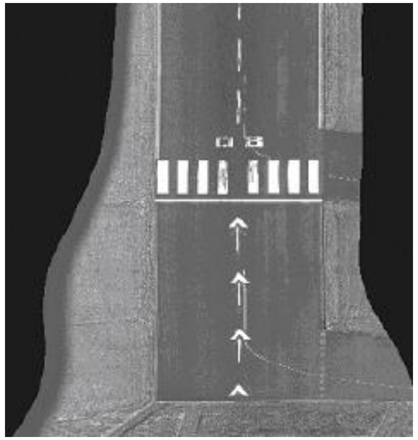
- Differential GNSS is the system of choice for high accuracy airport flight inspection reference systems
  - Several States had struggles to keep ILS operational
  - Often NO RFI SEEN ON GROUND, but DGPS INOP at 1000ft AGL
- **Alternatives:**
  - Modern Digital Radio Telemetry Theodolite
  - Automatic Laser Trackers
  - Inertial Reference Systems
    - sometimes with Camera Update
  - Optical Trackers
  - Hybridization



High Precision Reference Positioning in case of GNSS Jamming, Stanisak et al, IFIS 2024, Nagoya

Flight Inspection: A New Necessary Tool against GNSS RFI

- Spectrum Regulators usually don't have aircraft, while aviation carries the RFI Risks
  - EUROCONTROL Project Evaluated the use of CRPA for Flight Inspection in 2026
    - CRPA: Controlled Radiation Pattern Antenna – specific to GNSS
  - Evaluated trade-off between GNSS-specific antenna versus generic Direction-Finding Array
- **New Project seems to favor DF Array**

"Detection, Characterization and Localization of GNSS RFI", Stanisak & Wilkens, IFIS 2024, Nagoya

RF Measurements can't be argued with!

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

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*
  - **Flight Inspection remains an essential part of maintaining NAVAID Integrity**

- 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 / UAV could play a key role in understanding evolving GNSS spoofing threat to civil aviation
  - Risk mitigation requires understanding of interfering signals