GATEMAN
”GNSS navigation threats management on-board of aircraft”

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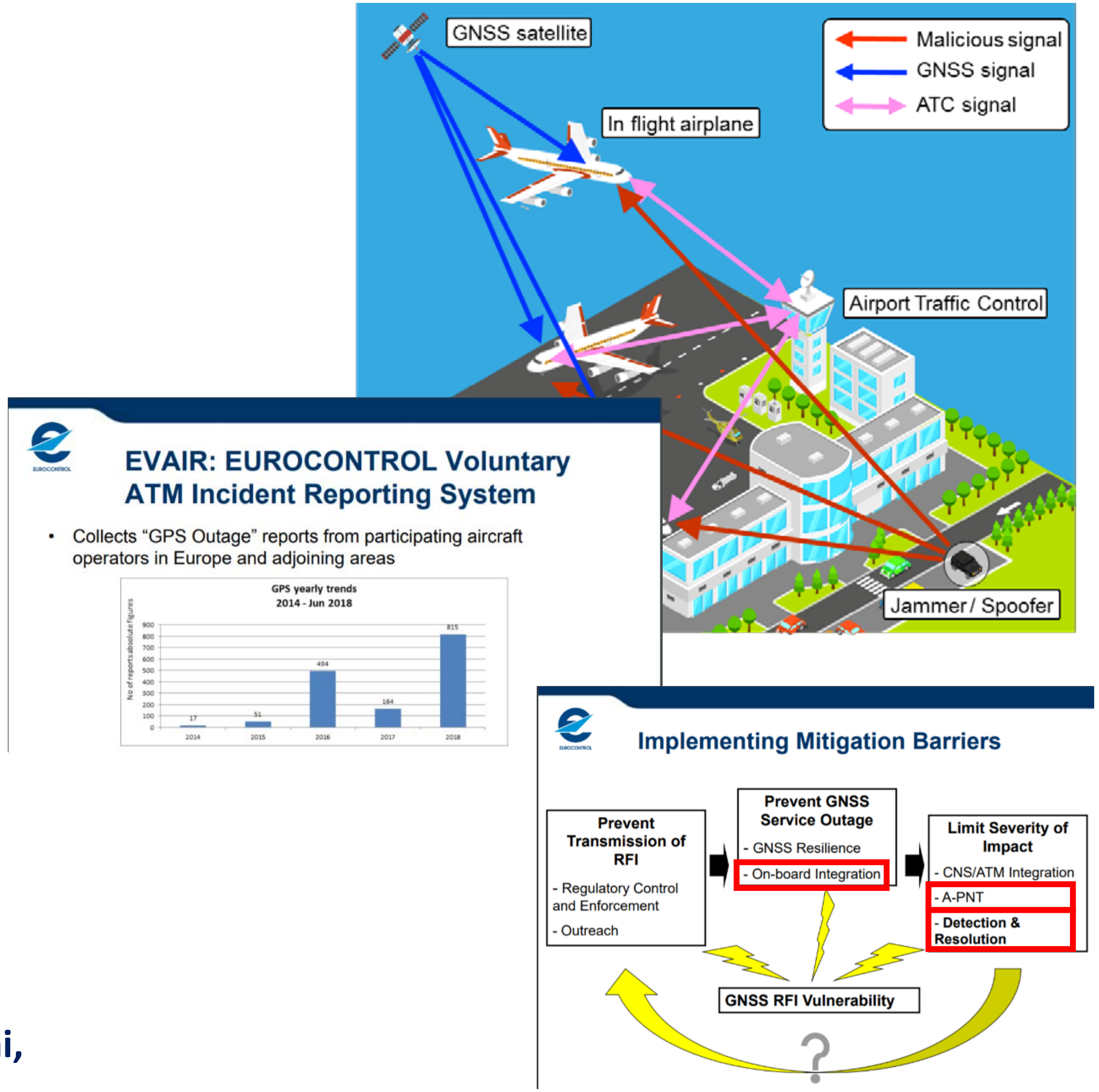
Overview

- Motivation
- Project’s Objectives
- Project’s Hypotheses
- Concept of Interference Management
- Results
- Benefits
- Publications
- Further information

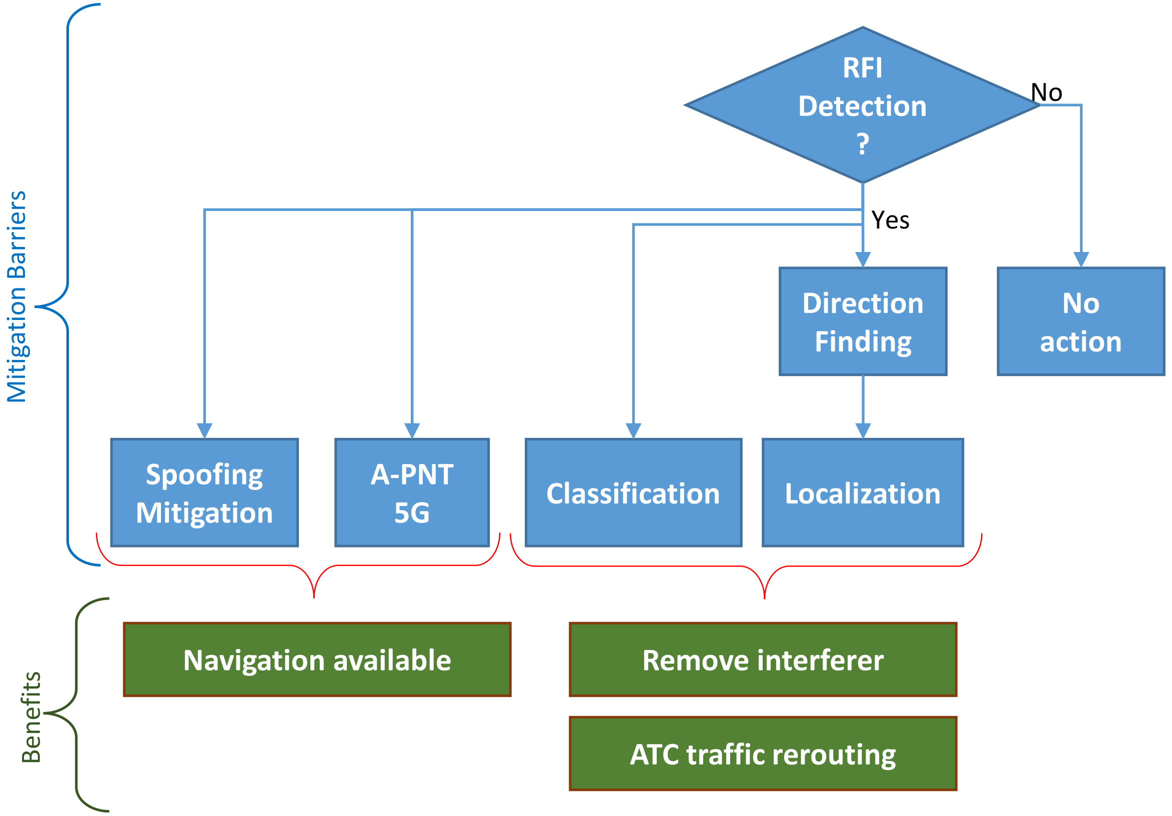
Motivation

- Interference threats in aviation: 47 times increase since 2014 to 2018.
- Mainly due to jamming. EVAIR (Eurocontrol Voluntary ATM Incident Reporting of GPS outages)
- GNSS RFI Mitigation: International Efforts to Protect Aviation
  - **David Duchet & Gerhard BERZ / EUROCONTROL NAV & CNS Unit**
  - **58th Civil GPS Service Interface Committee Meeting / Miami, 24 September 2018**



Project’s Objectives

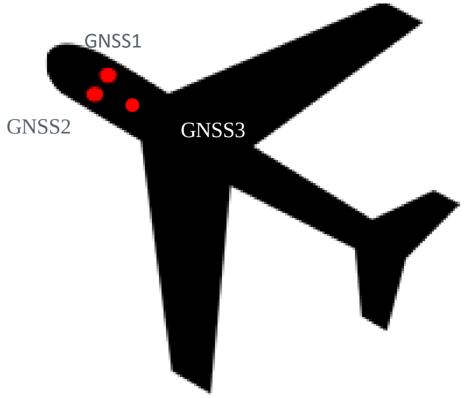
- Mitigation Barrier (MB1). Detection
  - **Novel concept for GNSS interferences management, based on:**
    - **Detection and localization of jamming on-board the aircraft.**
    - **Detection and localization of spoofing on-board the aircraft.**
- Mitigation Barrier (MB2). A-PNT
  - **5G ground cell stations networks.**
- Mitigation Barrier (MB3). Resilience
  - **Application of “spoofing monitoring” to mitigate the effects of spoofing.**



Project’s Hypotheses

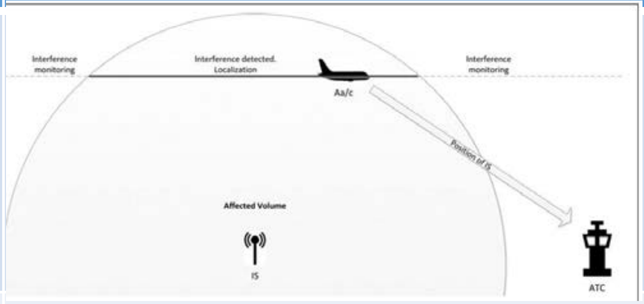
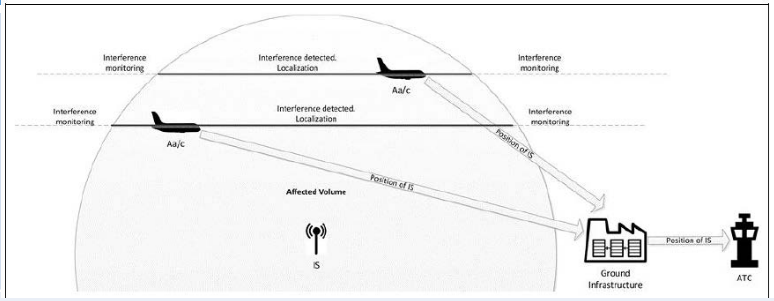
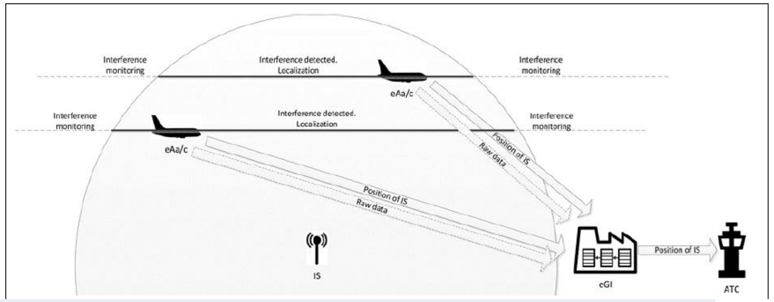
- Interference source
  - **Source on-ground (2D localization).**
  - **Static or quasi-static source (negligible speed compared to the aircraft).**
  - **1 single interferer.**

- Aircraft (minimize retrofit)
  - **Omnidirectional GNSS antennas.**
  - **GNSS antennas on top of the fuselage (used for navigation).**
  - **3 GNSS antennas (existing aircrafts are equipped with 2)**



Concept for interferences management

- Proposed Modes of Operation:

Mode	Detection & Autonomous Localization (D&AL)	Detection & Collaborative Localization (D&CL)	Detection & Enhanced Collaborative Localization (D&eCL)
			
Airborne (Data Processing)	2 omnidirectional GNSS antennas used for navigation + 1 additional GNSS antenna for interference management Data processing on-board: detection and localization of jamming and spoofing.		
Airborne (Data Link)	Low-rate (bytes/s): timetag, detection flag, estimated position of interferer…		Low-rate (bytes/s) High-rate (Kbytes/s): measurements on-board to be aggregated on-ground
Ground Infrastructure	None	Basic: information from aircrafts is aggregated to estimate a better position of interferer.	Improved: measurements from aircrafts are aggregated to estimate a better position of interferer.

Results. In-lab validation (TRL1)

- Jamming detection and DoA (Direction of Arrival)
  - **Best performing detection algorithms: AGC and time/frequency power detectors.**
  - **Best performing localization algorithms: AoA (Angle of Arrival) with the Minimum Variance Distortionless Response (MVDR) (or Capon) beamformer.**
- Spoofing detection and DoA (Direction of Arrival)
  - **Best performing detection algorithms: Dispersion Of Double Differences (D3).**
  - **Best performing localization algorithms: Precise And Fast GNSS Signal DOA estimator (PAF).**
- Interferer localization
  - **Inputs: user position + DoA + error estimation.**
  - **Best performing algorithm using MLE (Maximum Likelihood Estimation) solving non-linear equations using Levenberg-Marquard method.**

Results. In-lab validation

- Spoofing monitoring (TRL1)
  - **Best performing algorithms: Subspace Projection-based Spoofing Mitigation**
  - **Effective method to mitigate and cancel only GNSS signals that have been detected as "simplistic" spoofing (the code delays of the authentic and spoofing signal are not overlapped).**

- 5G A-PNT (TRL0)
  - **Using Orthogonal-Frequency Division Multiplexing (OFDM) transmitter with the main 5G parameters given by the 3GPP standard.**
  - **Theoretical performance of 5G positioning solutions based on TDoA and AoA are not conclusive. Further investigation on models is needed.**

Results. Open-field validation (TRL2)

- Field experiments at Instituto Tecnológico "La Marañosa" (ITM), managed by INTA (Instituto Nacional de Técnica Aeroespacial).
- Spoofing detection algorithm has good performances with real data.
  - **Detection rate >99.6%**
- Jamming detection algorithm has good performances with real data.
  - **Pd = 1 and Pfa ~ 1e-4. Very good results due to high power jamming.**
- Spoofing direction finding algorithm has acceptable performances.
  - **DoA with limited accuracy due to the estimation of receiver bias.**
- Jamming direction finding algorithm has invalid performances.
  - **DoA accuracy not evaluated due to unreliable raw data acquired in tests (definition of the trials, acquisition board…)**

Benefits

- Reduction of the time to detect and localize interfering sources:
  - **Thanks to on-board solutions.**
  - **Enabling fast interferer deactivation by the National RF Spectrum Agency .**
  - **Reduction of the duration of GNSS outages.**
- Cost effectiveness:
  - **minimal additional infrastructure on-board.**
- RFI threat management enables traffic rerouting:
  - **Thanks to the localization of the interferer**
  - **Thanks to the estimation of the affected volume.**
  - **ATC may mitigate the operational impact of interference rerouting traffic to areas not affected by the interference.**

Publications

List of peer-reviewed publications:

R. Morales Ferre, P. Richter, A. De La Fuente, and E.S. Lohan, "In-lab validation of jammer detection and localisation algorithms for GNSS", accepted at IEEE ICL-GNSS, Jun 2019, Nuremberg, Germany

DOI: 10.1109/ICL-GNSS.2019.8752944

R. Morales-Ferre, P. Richter, E. Falletti, A. de la Fuente, and E.S. Lohan, "A survey on coping with intentional interferences in satellite navigation for manned and unmanned aircraft", accepted at IEEE Communications Surveys and Tutorials.

DOI: 10.1109/COMST.2019.2949178

Nguyen V. H., Falco G., Falletti E., Nicola M. (2018) A dual antenna GNSS spoofing detector based on the dispersion of double difference measurements. NAVITEC 2018, ESA-ESTEC, The Netherlands, 5-7 December 2018.

Falco G., Nicola M., Falletti E., Pini M. (2019) An Algorithm for Finding the Direction of Arrival of Counterfeit GNSS Signals on a Civil Aircraft. ION GNSS+ 2019, Miami, FL, 16-20 September 2019.

M. Nicola , G. Falco, R. Morales Ferre, E. S. Lohan, A. de la Fuente and E. Falletti (2020), "Collaborative Solutions for Interference Management in GNSS-based Aircraft Navigation", re-submitted at MDPI Sensors.

Further information

http://gateman.gmv.com/

GATEMAN consortium:

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