

Enabling Aviation Infrastructure

SESAR Overview

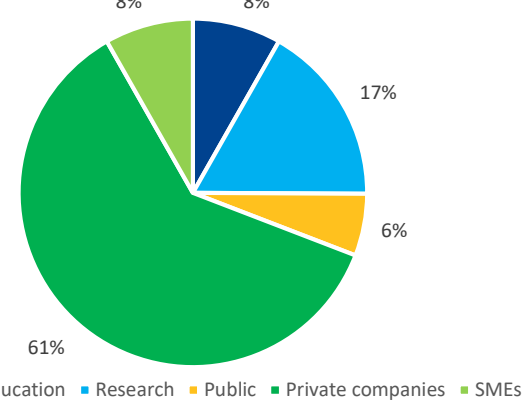
Paul DUNKLEY
SJU Programme Manager
Enabling Aviation Infrastructure
SESAR Joint Undertaking

SESAR: Technological pillar of Single European Sky and key enabler for the Aviation Strategy

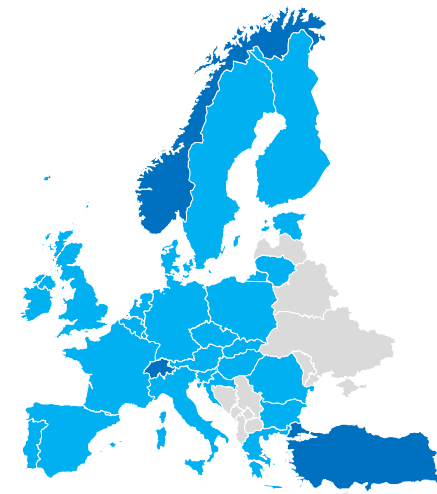


SESAR 2020 projects:
blended academic & industrial expertise

Types of beneficiaries (Sept. 2018)



26 EU Member States participating



EU Member States with SESAR 2020 funding

Third-countries with SESAR 2020 funding (also incl. Israel, Australia, United States, Canada...)

SESAR Innovation Pipeline: integrated approach



EXPLORATORY
RESEARCH

Explores new concepts beyond those identified in the European ATM Master Plan or emerging technologies and methods. The knowledge acquired can be transferred into the SESAR industrial and demonstration activities.



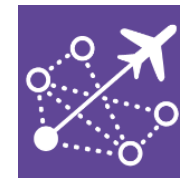
INDUSTRIAL
RESEARCH
& VALIDATION

Assesses and validates technical and operational concepts in simulated and real operational environments according to a set of key performance areas. This process transforms concepts into SESAR Solutions.



VERY LARGE
SCALE
DEMONSTRATIONS

Tests SESAR Solutions on a much larger scale and in real operations to prove their applicability and encourage the early take-up of solutions.

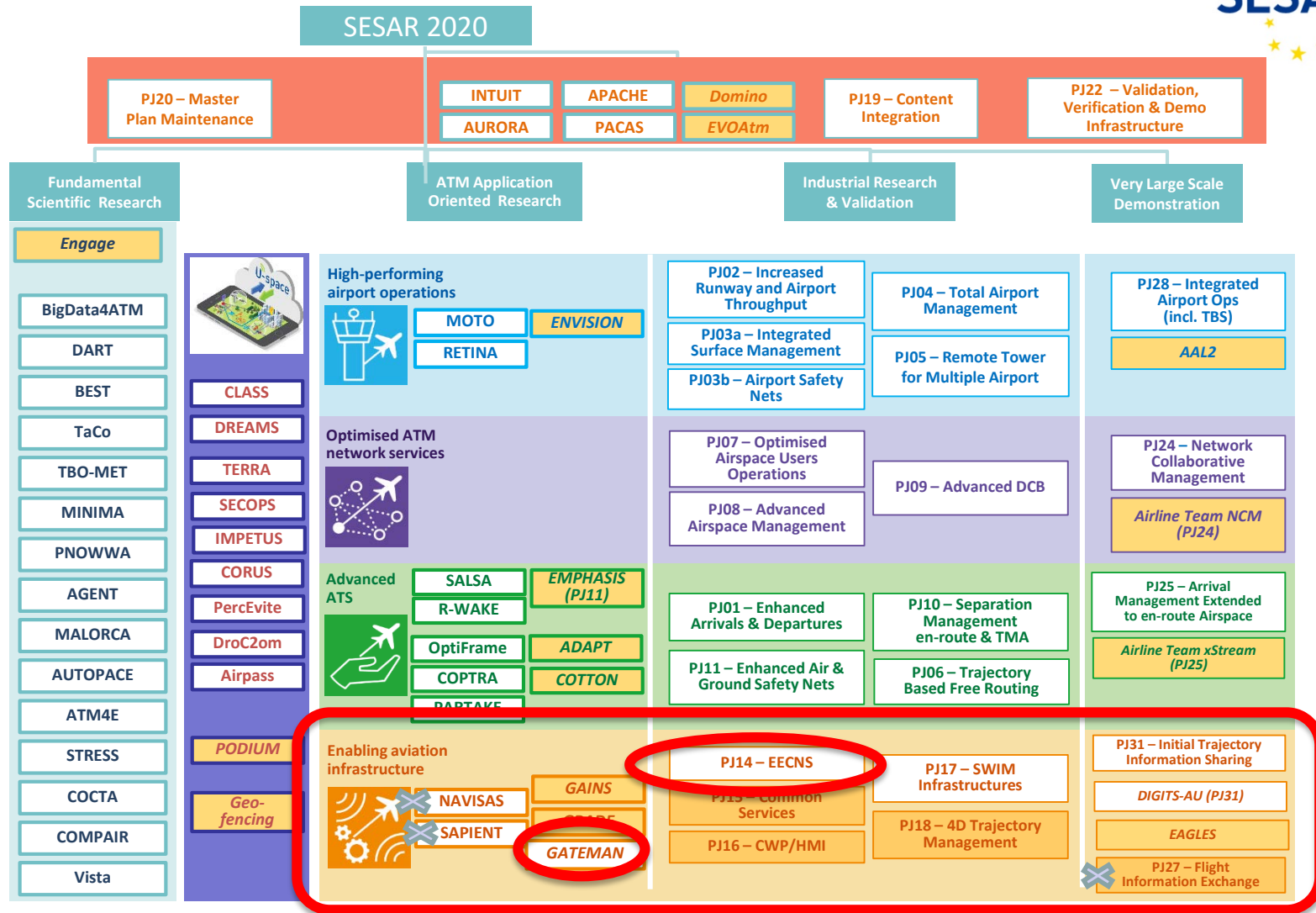


DELIVERING TIMELY SOLUTIONS

- **63 SESAR Solutions** and **candidate solutions** in the pipeline
- **40+ already under deployment** across Europe
- Disseminated through **EU aviation standards**
- Clear associated benefits: **safety, efficiency, capacity and the environment**
- **Globally applicable**



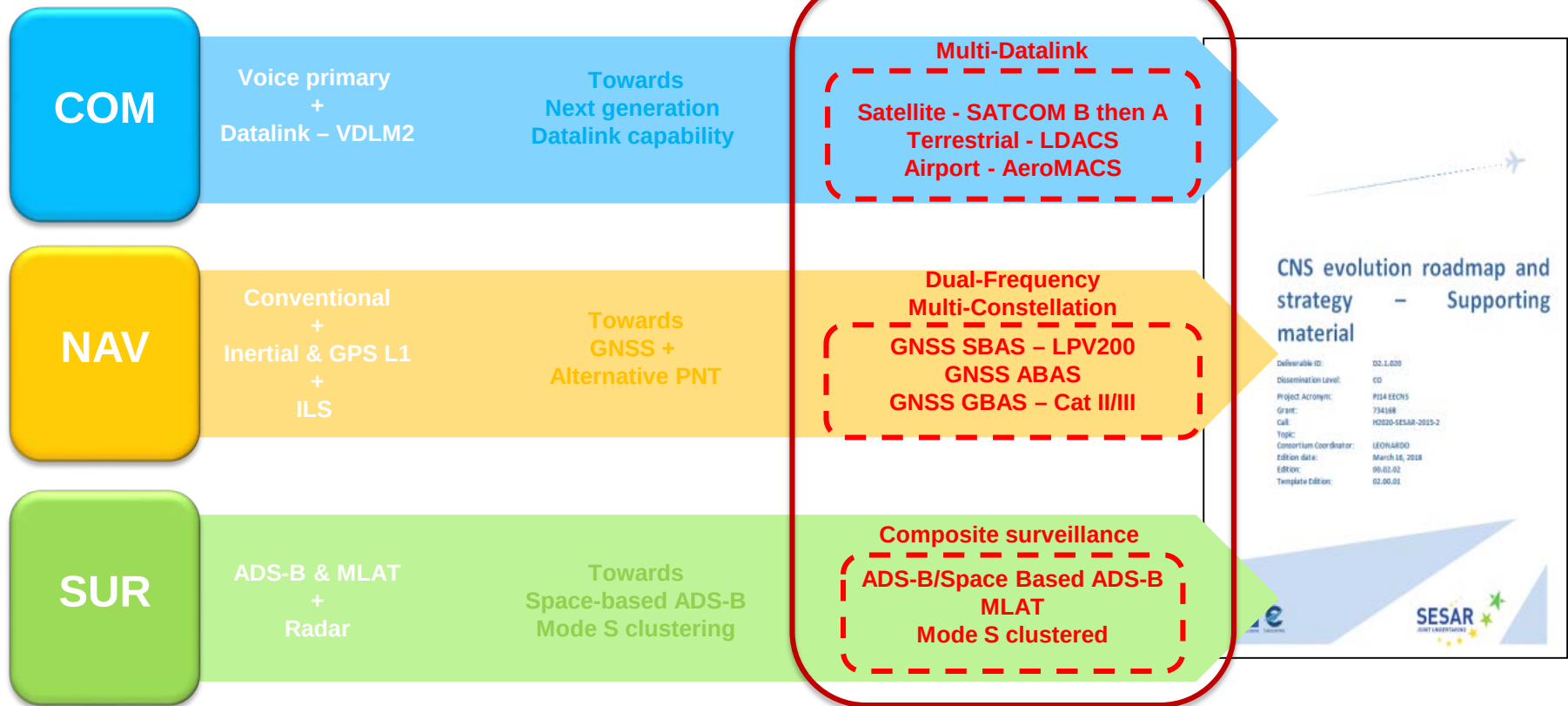
SESAR Programme Overview



CNS Roadmap & Strategy



2025+ Rendezvous



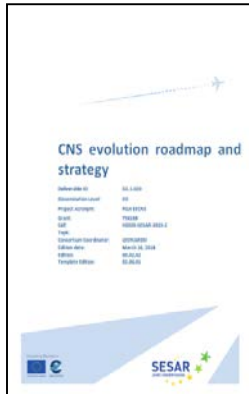
CNS Roadmap & Strategy within European ATM Master Plan



Strategy for
Future CNS
Evolution

Combining Top-
Down &
Bottom-Up

CNS
Roadmap
& Strategy



CNS
Solutions



&
Regulation



Bucharest, 27-30 May 2019





Thank you !



Enabling aviation infrastructure

Future Terrestrial Datalink - LDACS

PJ14 EECNS

**Christoph Rihacek
Frequentis AG**

SESAR2020 PJ.14-02-01 Solution Lead

Outline

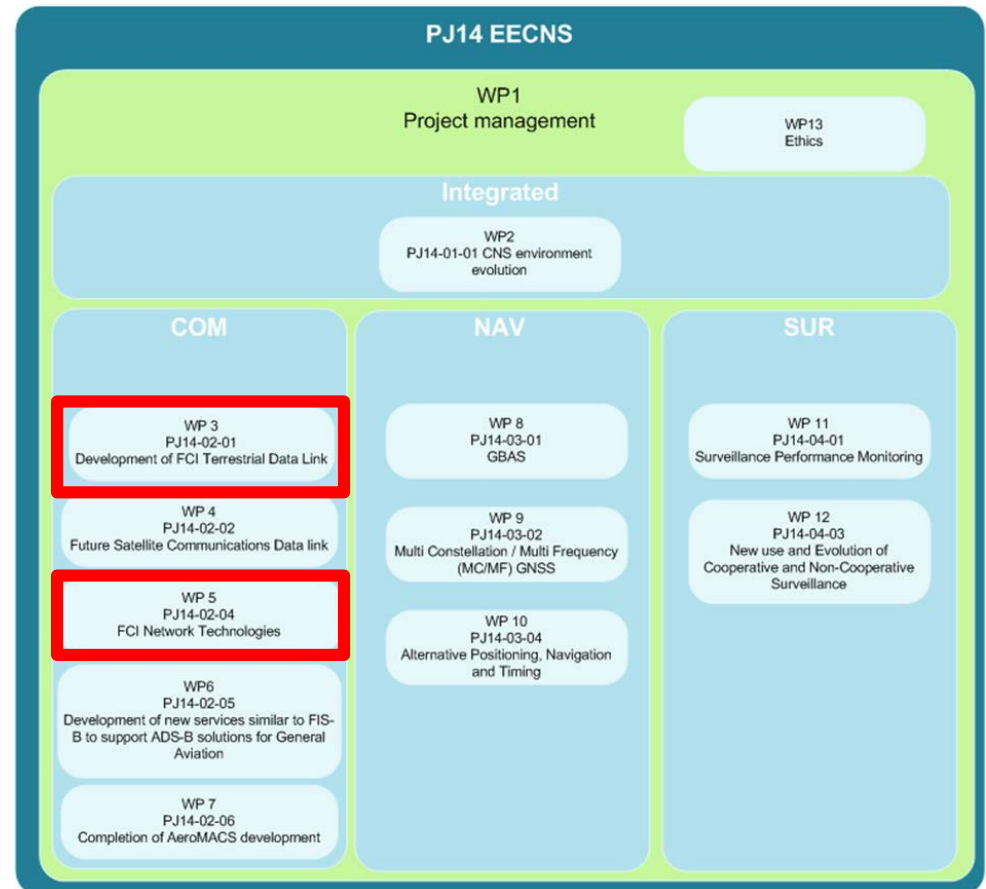


- *Future COM Infrastructure (PJ.14-02.04)*
- *Future Terrestrial Datalink - LDACS (PJ.14-02.01)*
- *Standardisation Activities*

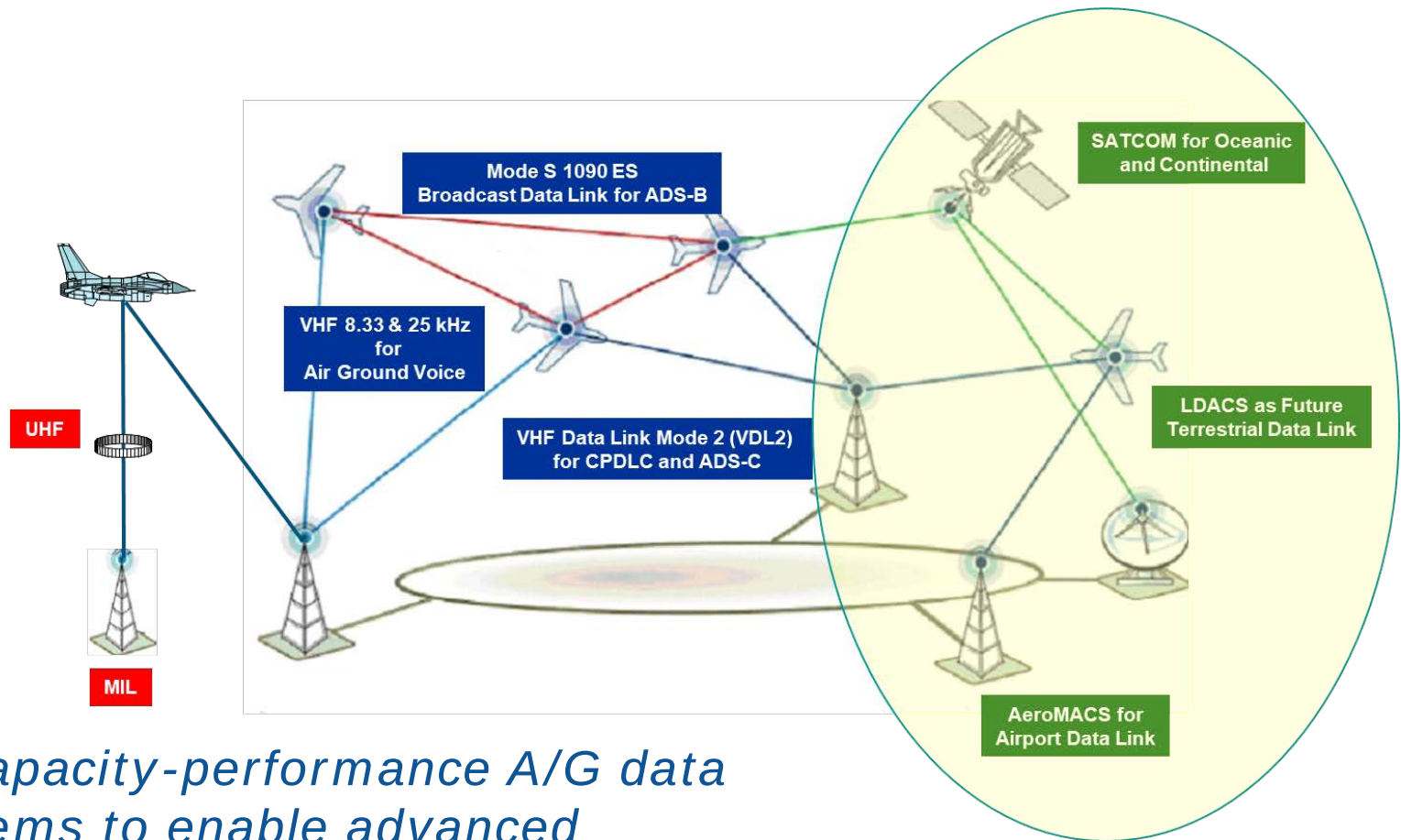
Future COM Infrastructure



- *1 transversal (CNS)*
- **5 COMMUNICATIONS**
- **3 NAVIGATION**
- **SURVEILLANCE**

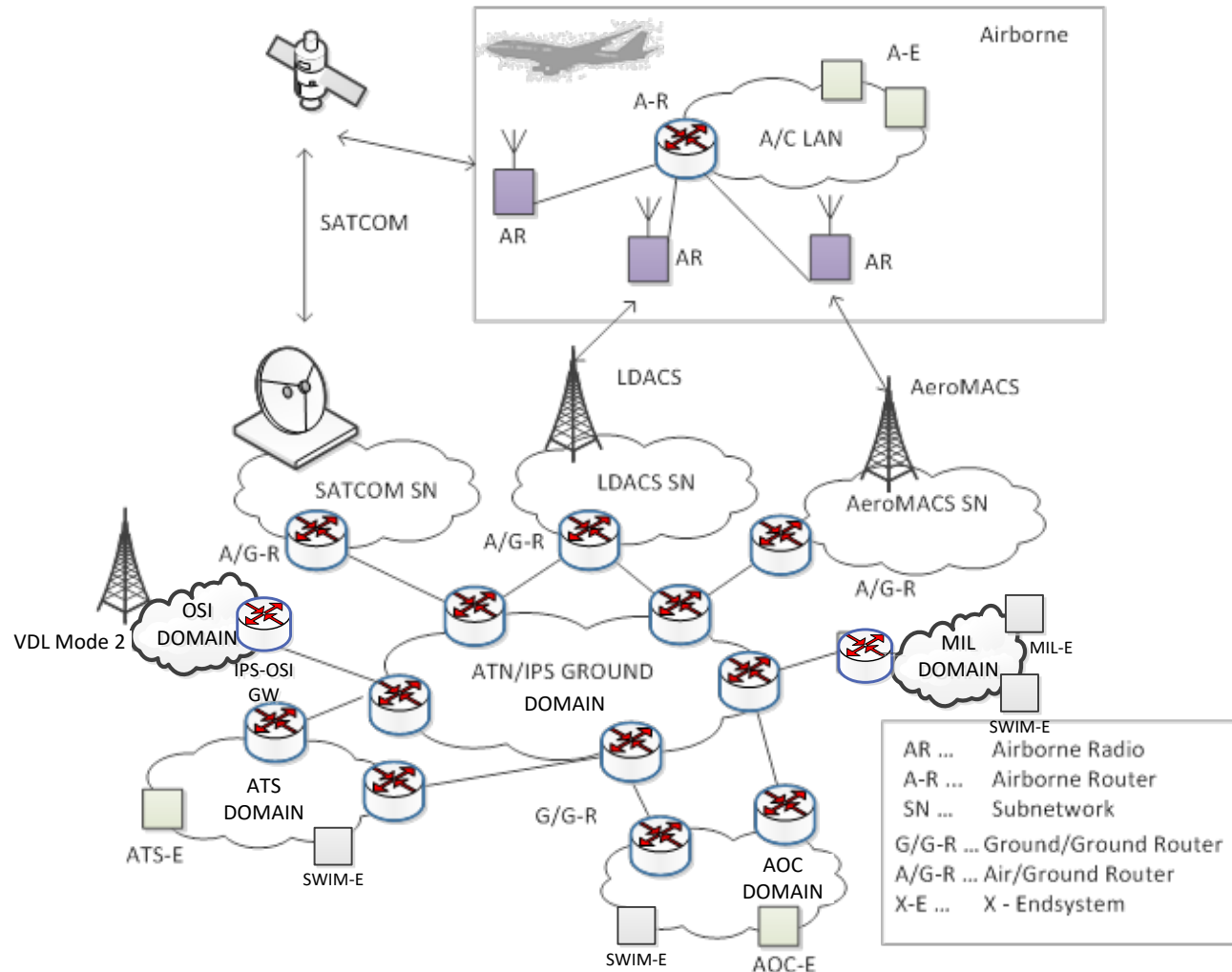


Project (PJ)14 – CNS: 11 Solutions



Higher capacity-performance A/G data link systems to enable advanced SESAR2020 concepts

Future Communications Infrastructure (FCI)



Why LDACS ?



- *Reliable (terrestrial) datalink is an essential building block of the European vision for the future communication infrastructure (FCI).*
- *Establishing secure communication between the ground and the air is vital to support the growth in traffic volume and complexity.*
- *The operational concept of trajectory management in 4D needs to be supported by a reliable, scalable, modular and efficient datalink technology.*

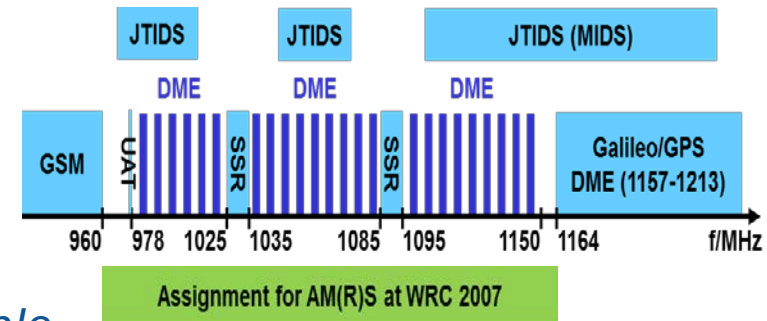
➔ LDACS (L-Band Digital Aeronautical Communication System)

LDACS – Design Challenges



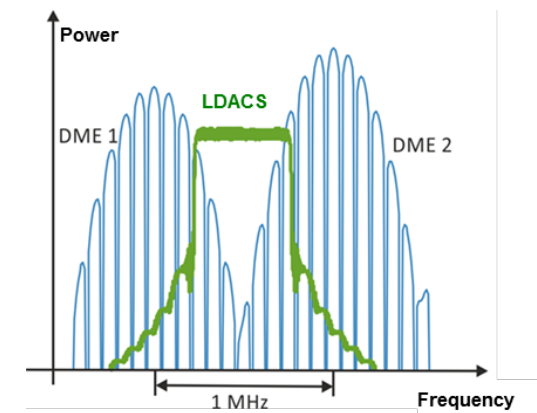
Choice of Frequency Band (L-Band)

- Aviation band with AM(R)S allocation
- Drawback: strongly used by aeronautical navigation systems, esp. DME (Distance Measuring Equipment)
- COTS communications systems not applicable → special design required



Approach: Design of LDACS as Inlay System

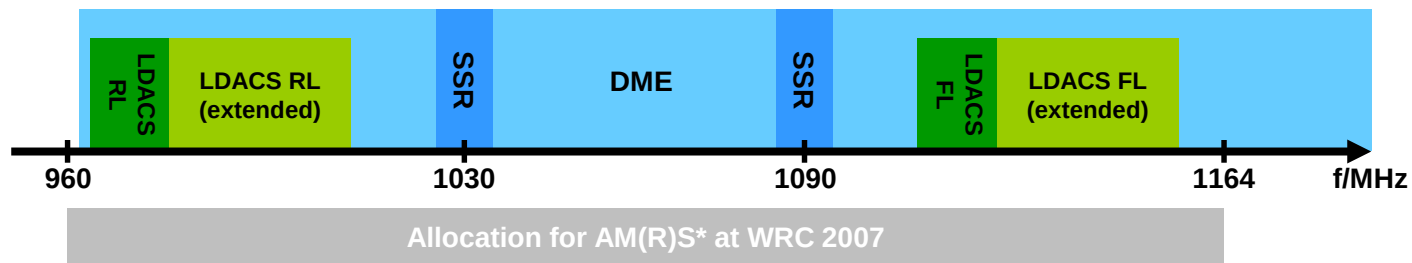
- LDACS inlay approach: deploy LDACS between DME channels
- Ensuring L-band compatibility:
 - Suppression of out-of-band radiation
 - Mitigation of interference impact of legacy L-band systems on LDACS



LDACS – Frequency Bands



LDACS FL (Forward Link) and RL (Reverse Link) Frequency Bands



*AM(R)S - Aeronautical Mobile (Route) Service

LDACS FL: 1110 – 1156 MHz

(initial deployment: 1110 – 1125 MHz)

LDACS RL: 964 – 1010 MHz

(initial deployment: 964 – 979 MHz)

LDACS – Design and System Characteristics

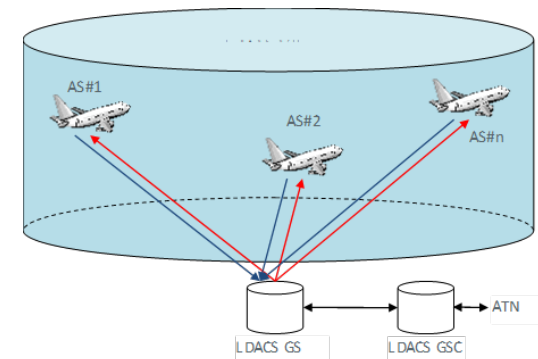


Basic Design Considerations

- Apply modern state-of-the-art technology like current/future mobile radio standards (LTE/4G)
 - Orthogonal Frequency-Division Multiplexing (OFDM), highly flexible and scalable
 - Strong coding and adaptive coding/modulation
- Apply frequency-division duplex (FDD) due to limited bandwidth available with inlay approach
- Apply interference mitigation due to inlay approach

System Characteristics

- **Cellular** communications concept
- Support of „**seamless handover**“
- Support of **data and voice**
- Support of **Quality-of-Service**
- Support of **ranging** functionality (APNT*)
- Support of **A/A** communications



*Alternative Positioning Navigation and Timing

Scientific & technical goals



- *Develop and standardize LDACS, the candidate future terrestrial data link system (that can cope with the increased capacity).*
- *Develop and verify LDACS prototypes, which will be integrated into an FCI validation platform (Solution PJ14-02-04).*
- *Address transversal topics and concepts, including seamless transition from existing data link technologies to LDACS and the inclusion of a ranging functionality.*

Planned Solution Maturity: TRL4 (A/G) and TRL2 (A/A) by end of 2019 (wave 1)

LDACS to be continued in Sol #60 during wave 2 (offer provided)

FCI Terrestrial Data Link (PJ.14-02-01)

LDACS: Partners



1	Frequentis (FSP) – Solution Lead	
2	Leonardo	
3	Airbus	
4	DLR (AT-One)	
5	EUROCONTROL	
6	Airtel (NATMIG)	
7	NATS	
8	SITA (as subcontract to THALES AIRSYS)	

The main achieved & expected results



Current Status:

- *Completion of LDACS A/G specification*
- *Development of High Level Architecture and Initial Deployment Options and Recommendations*
- *Contributions to ICAO PT-T / coordination with ICAO NAV Systems Panel Spectrum Subgroup*

Next Steps:

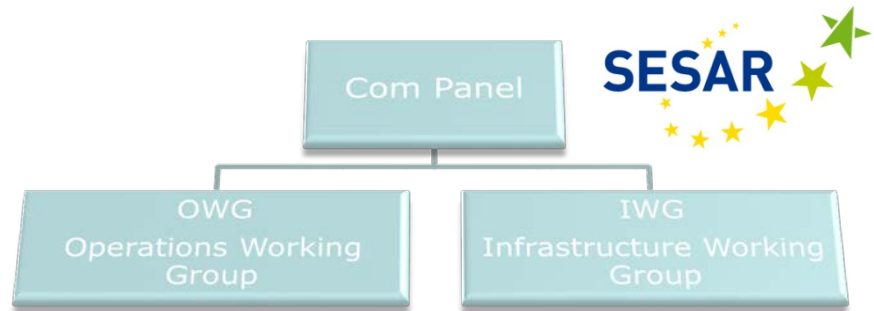
- *Complete LDACS Prototypes validation exercises*
- *Compile the Validation Report*
- *Continue liaison with ICAO PT-T (prepare inputs required for drafting LDACS standardization documents)*

Potential gaps and challenges

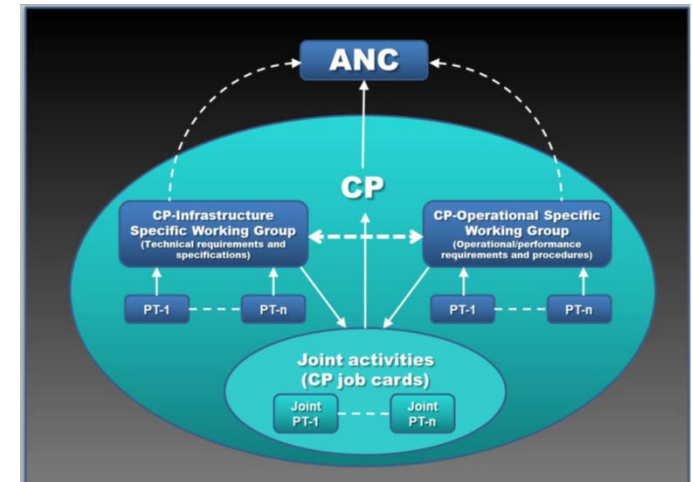


- *Frequency band targeted for LDACS deployment (L-band) is currently primarily used by navigation systems*
- *Combability between LDACS and legacy systems has to be proven*
- *Other, non-aeronautical, systems are trying to get some temporary frequency allocations in the L-band (e.g., PMSE - programme-making and special events (wireless microphones. ..)*

Impact

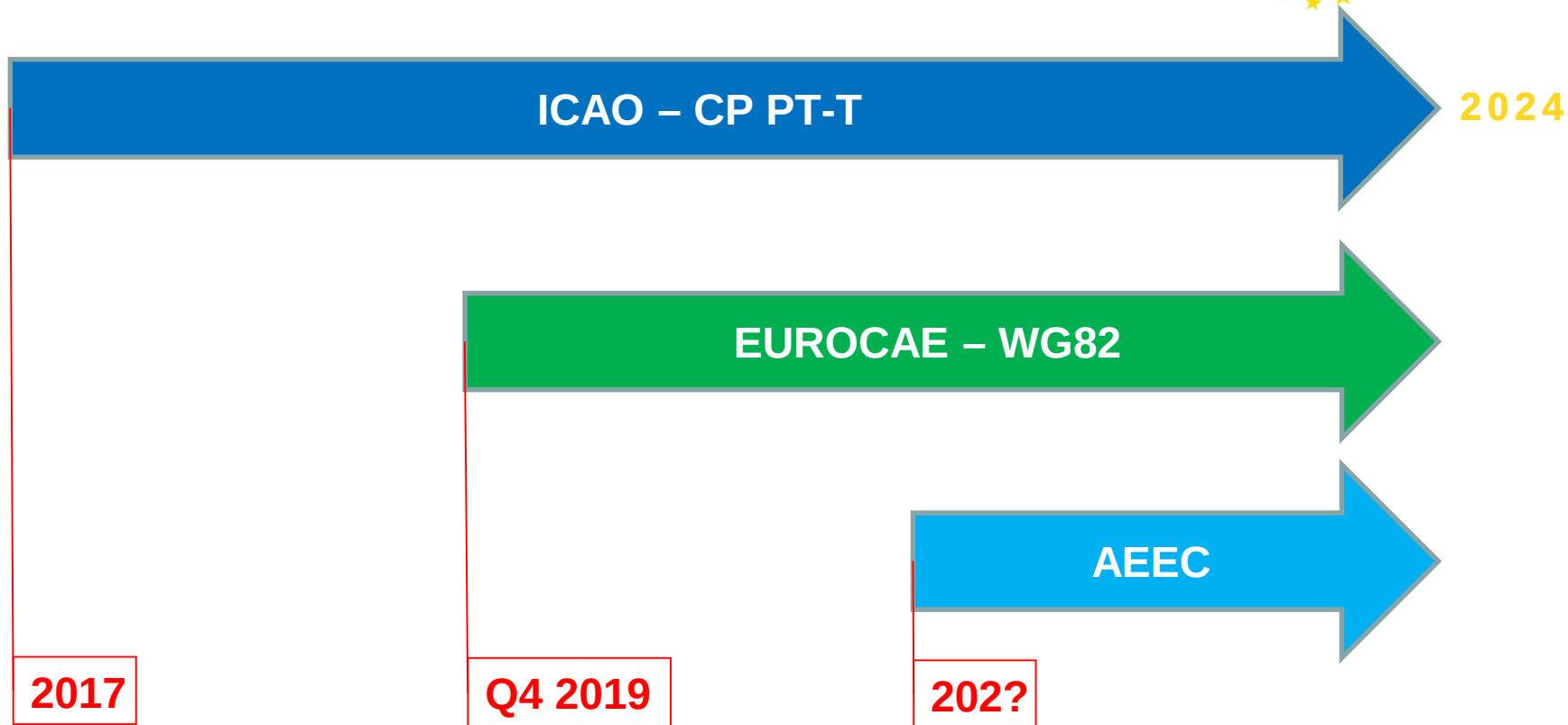


- *Standardisation*
 - ICAO in Infrastructure Working Group (IWG)
 - Project Team Terrestrial (PT-T)
- *Applicability of SARPs aimed for Q4/2024*
 - Initial SARPs* for LDACS: Delivered in Q4/2018 (affected document = ANNEX 10 Vol III)



*Standards and Recommended Practices

Timeline on Standardisation



Timeline

Useful info and acknowledgements



SESAR2020 Solution PJ.14-02-01

<http://https://www.sesarju.eu/sesar-solutions/future-communication-infrastructure-fci-terrestrial-datalink>

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 824238



Thank you !



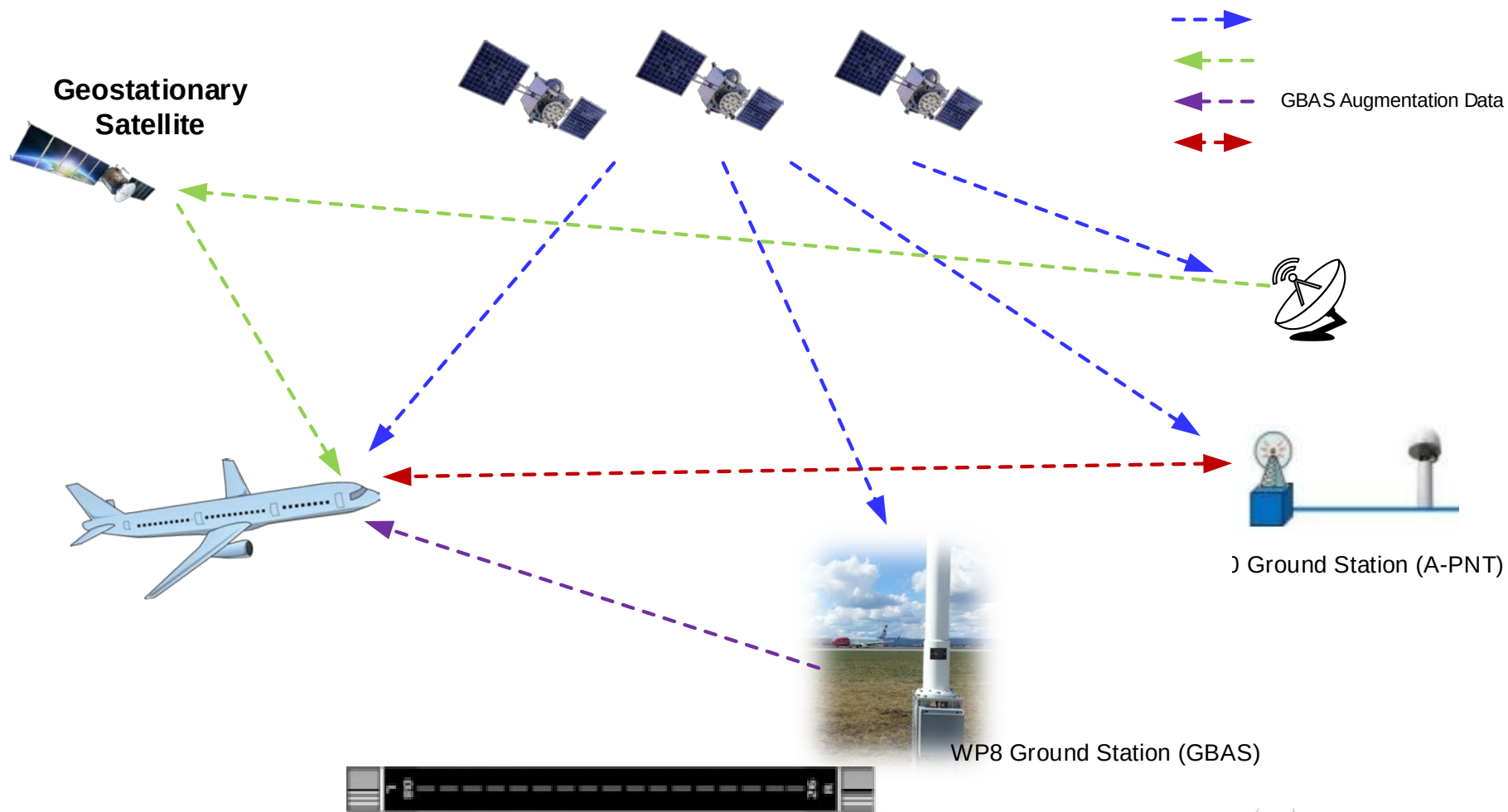
Enabling Aviation Infrastructure

Ground-Based Augmentation Systems (GBAS) Cat II/III

SESAR project PJ.14
Hugo Moen
Indra Navia AS

Scientific & technical goals

NAVIGATION SOLUTIONS IN SESAR 2020 PJ14



Scientific & technical goals

SESAR 1 -15.3.6/7-& SESAR 2020 –PJ14-03-01

TRL2

TRL4

TRL6

Target Release
R9

27/11/2019
GAST F

27/11/2019
GAST D extended scope
(GAST D core at TRL6 (SESAR1))

- GBAS GAST D - CAT II/III Landing System
 - Globally – for all regions
 - For all airport environments
- Research on GBAS GAST F
 - CAT II/III
 - Dual Constellation, Multiple Frequency
- Extending GAST D to complex condition
 - Ionospheric challenges
 - Equatorial and Nordic regions
- Extending GAST D to complex environments
 - VDB coverage at complex airports
 - Handling RFI/Jamming threats
- Further developing GAST F concept

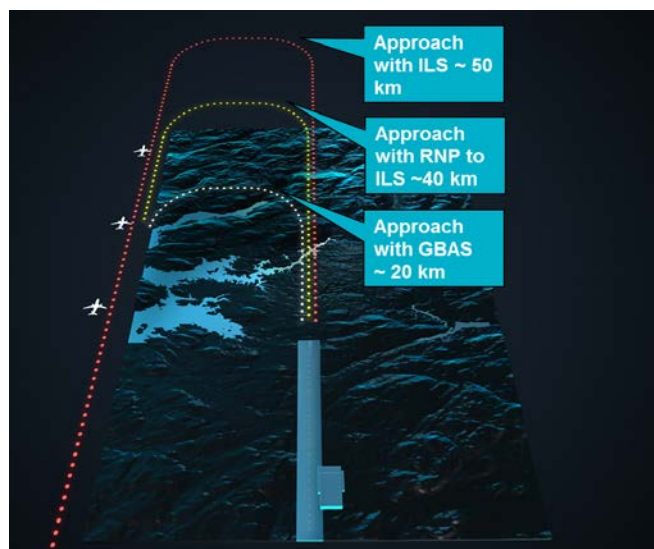
NORMARC 8100 GBAS GAST D SESAR Installations

- Frankfurt (Germany)
- Oslo (Norway)
- Tenerife (Spain)



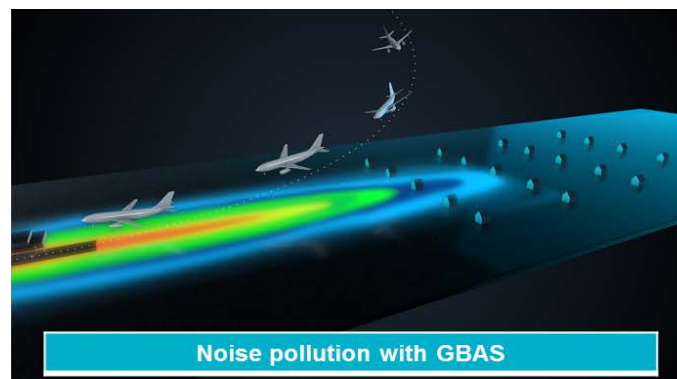
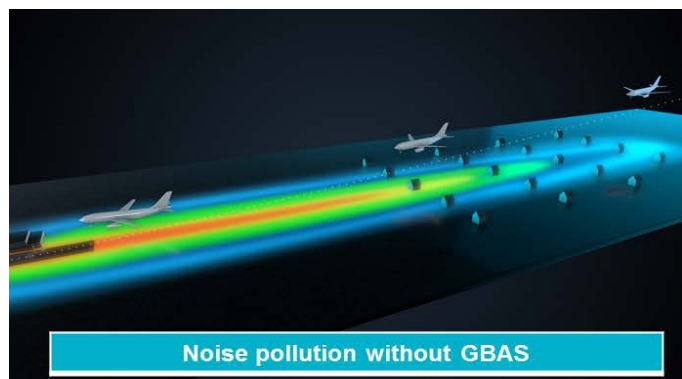
The main achieved & expected results

Flexible approaches



RNP, RNP to GLS, Independent parallel operation

Greener landings ; Efficiency, Noise, Emission, Fuel, and a happy neighborhood

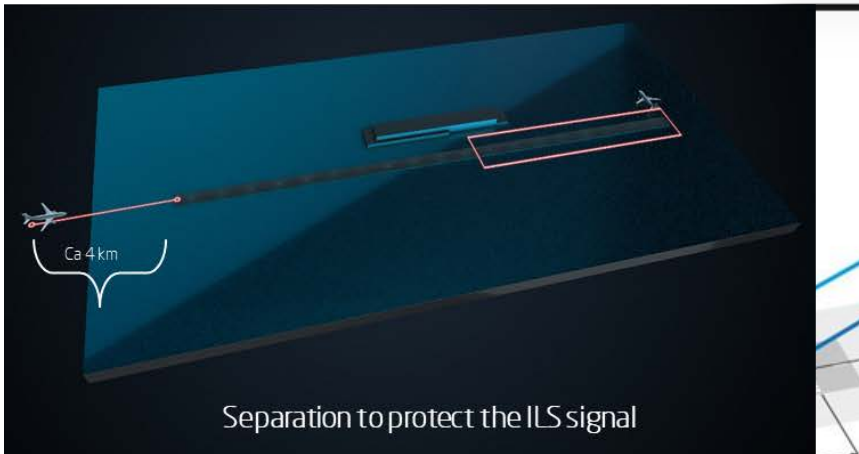
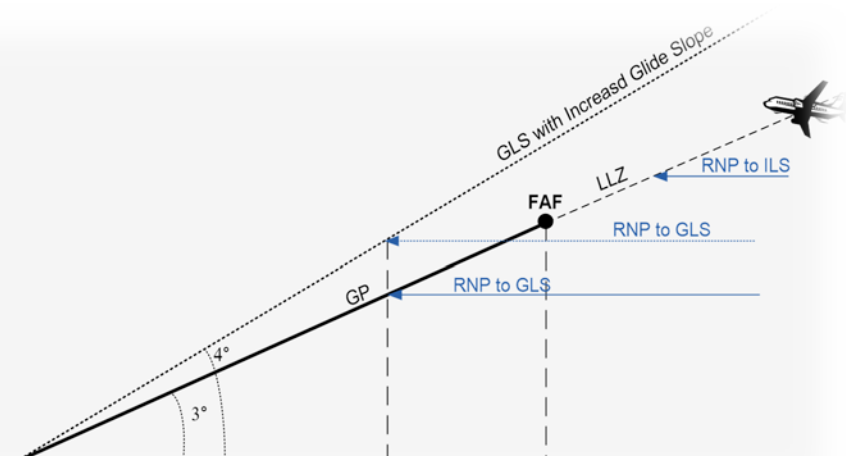


The main achieved & expected results

- GBAS GAST D (CAT III)

Increased Glide Slope (IGS) & Multiple Aiming Points (MRAP):

- Flexible approaches
- Greener landings
- Reduced wake turbulence effects



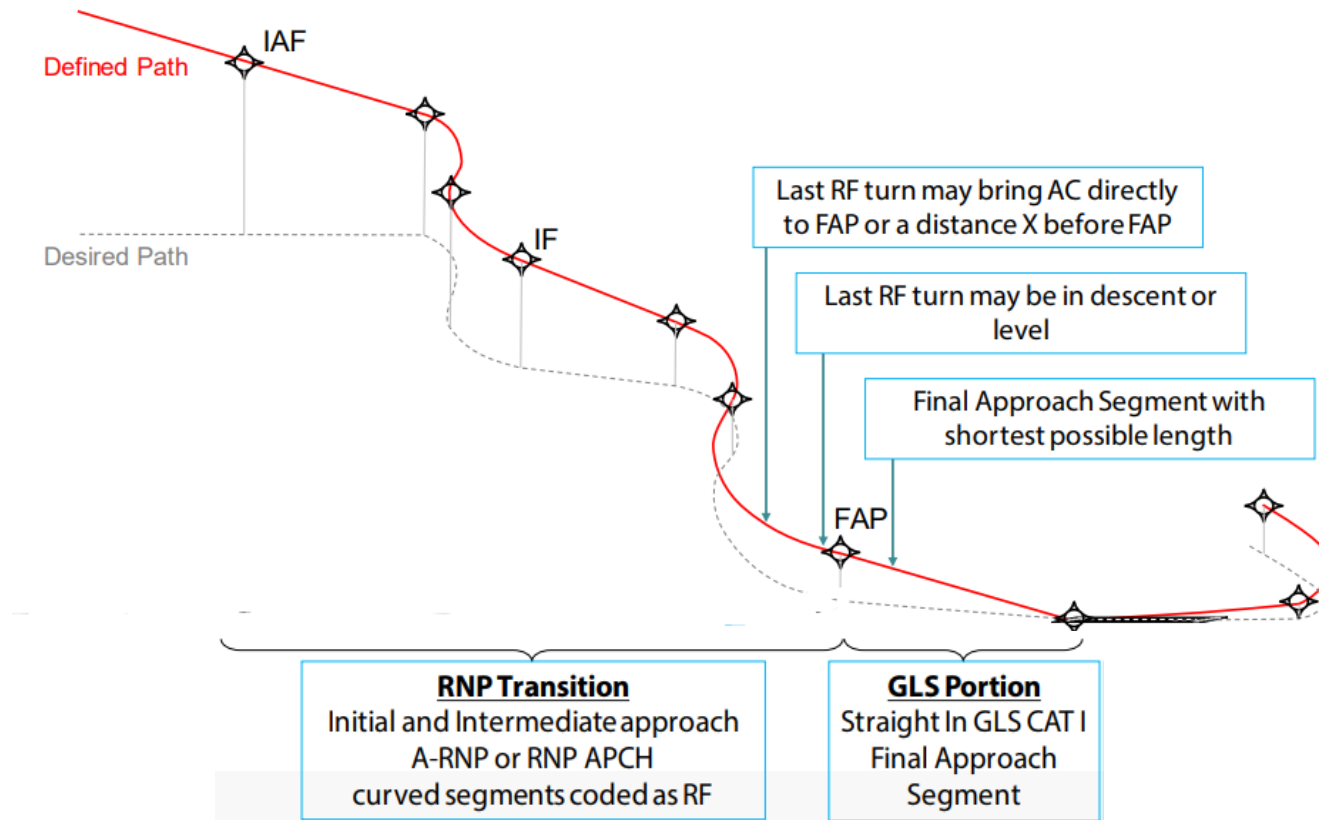
Potential gaps and challenges

- Technical and Operational Approval
- Synchronized deployment ; The “Chicken and Egg Situation”:
 - **Unless a significant number of airports invest in GBAS CAT III ground stations, the airlines will not make the required investments.**
 - **Likewise, airports and ANSPs are reluctant to invest as long as aircraft equipage is low.**
- Further mature GAST F concept targeting TRL4
- Applied to continue these activities in SESAR 2020 wave 2 PJ14-W2-79 & VLD01-W2 DREAMs

Cross-cutting issues (tech. & non-tech.)

Combining two technologies to provide extra benefits

RNP to GLS Concept – SESAR P6.8.5



Impact

- *The GBAS GAST D standard developed under SESAR became effective under ICAO Annex 10 as of Nov 2018*
- *The technology is ready;*
 - ***A synchronized GBAS GAST D implementation will lead to environmental, cost, capability and safety benefits for airports, airlines and air navigation service providers***
 - ***A wide European GBAS deployment is an enabler to realise the Single European Sky objectives***

Delivering the Single European Sky

High Level objectives

- Enable a 3-fold increase in capacity
- Reduce delays on the ground and air
- Enable a 10% reduction in environmental effects
- Improve safety
- Reduce cost



Thank you !



Enabling Aviation Infrastructure

Composite Surveillance

Composite Surveillance
Miguel Muñoz
Indra

Scientific & technical goals

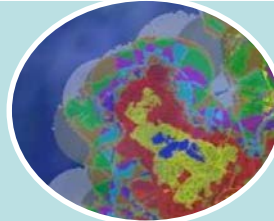


Surveillance goals is moving towards a PBS concept based on ADS-B and supplemented by a Minimum Operating Network including Mode S Radar, MLAT and primary surveillance.

In this sense, **Composite surveillance** enables to:



Increase **ADS-B Integrity & Security**
through Data
Validation



Infrastructure
Rationalisation



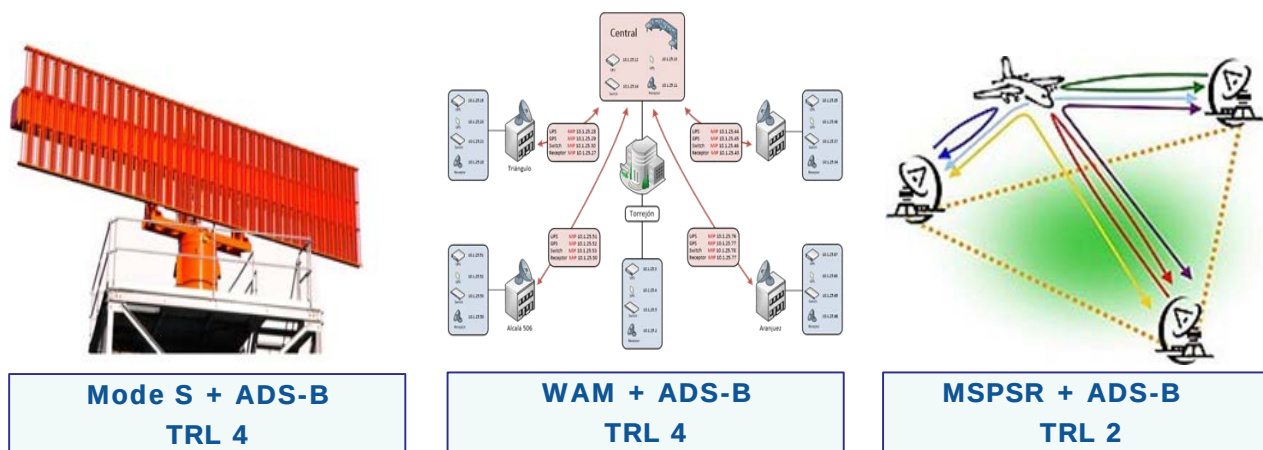
Reduce RF spectrum
load produced by
Surveillance sensors

The main achieved & expected results



“**Composite**” systems constitute supplemental system capabilities that are aiming at materializing the benefit that can be achieved by a system comprising both **ADS-B** and **independent channels** within a single physical SUR Sensor system.

WP12 has developed Composite systems of different kind



The main achieved & expected results



Benefits for WAM system

- **RF spectrum:** Decreasing RF load (target acquisition, RF downlink)
- **Security:** by supporting the detection of ADS-B avionics anomalies – spoofing
- **Safety:** by identifying “rogue”
Version 0 / 1 ADS-B Out installations
- Monitoring ADS-B performances
- **Others:** Duplicated ICAO address Resolution,

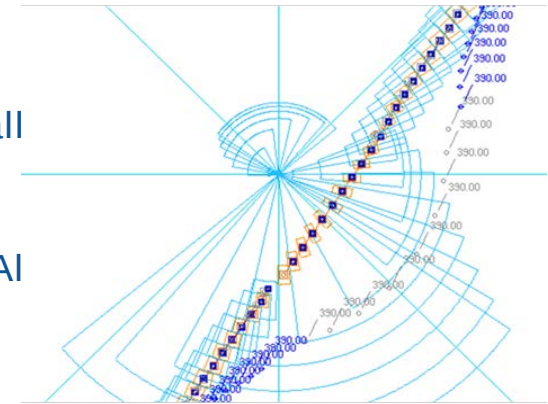


The main achieved & expected results

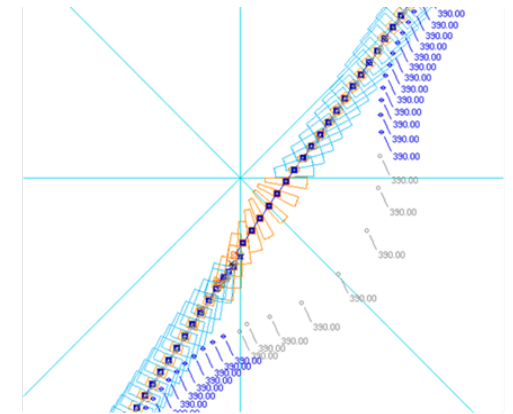


Benefits for Mode S system

- **Passive Acquisition of targets.**
 - With the ADS-B there is no need to have the All-Call interrogations
 - Targets that are on the ground (i.e. in airport runways or taxi areas) are not replying to Mode S All Call interrogations, improving surface detection.
- **Cone of silence reduction:** The radar system continues having ADS-B information while the target is crossing the MSSR cone of silence.
- **Performances enhancement:**
 - Using ADS-B information while in cone of silence, reflections, support during maintenance, Interrogation code conflict.
- Benefits for MSPSR
 - **ADS-B Validation:** and consistency validation with MSPSR data.



NO ADS-B integrated (wide cone)



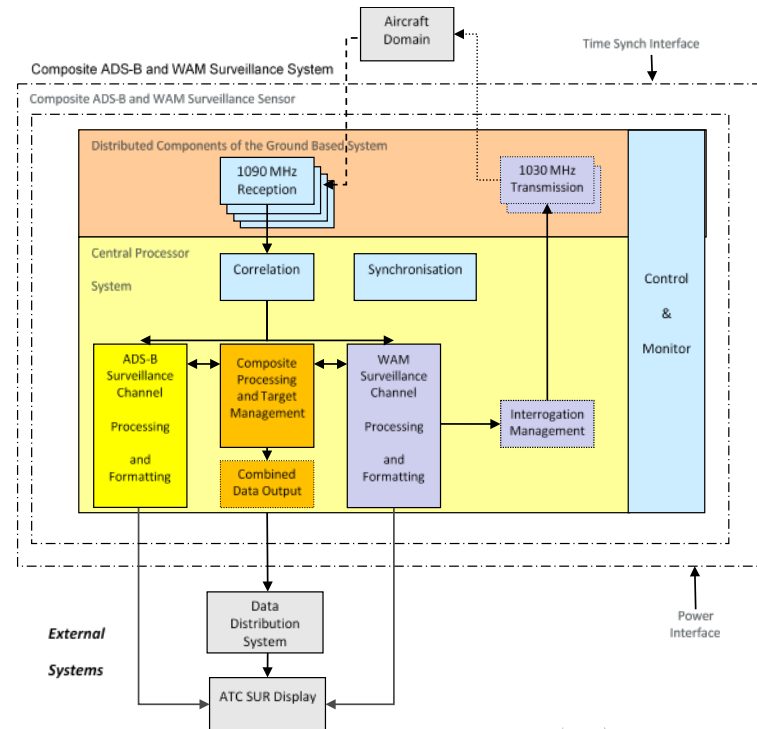
ADS-B integrated (smaller cone)

The main achieved & expected results



Composite surveillance Benefits

- *One system to provide different surveillance layers: Inclusion of ADS-B ASTERIX CAT021 in addition to standard outputs (CAT020, CAT048)*
- *Information about integrity validation is provide through ASTERIX CAT021 dataflow.*



Potential gaps and challenges



Slow process in the deployment of new technology.

Certification process and standardization is slow compared to the technological developments.

Examples in ATM:



PASSIVE RADAR

ALREADY DEPLOYED for military solutions

STANDARD started by EUROCAE WG-103.



VIDEO SURVEILLANCE

REMOTE TOWER solutions

Multi-sensor surveillance
SESAR2020. PJ14-4-3. Task 4.

No **STANDARD** or **Regulation**
ED-240A (Draft); NPA 2017-21



RPAS

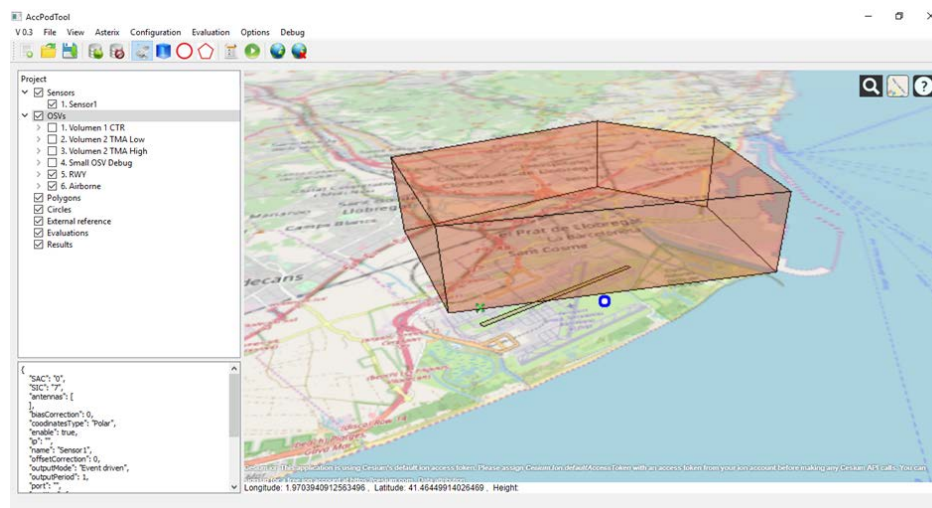
STANDARDS: started by EUROCAE WG-105 & EUSCG

Regulation: Open & specific Expected by 2019

Cross-cutting issues (tech & non-tech.)



- **WP11 Surveillance performance monitoring** tools for real time evaluation of sensors in the different environments.



- **WP12 Multisensor surveillance** for small airports. Merging of different technologies to create a multi-sensor kind providing enough performances.

Cross-cutting issues (tech & non-tech.)



- **WP12 Secured surveillance**

Development of secured surveillance systems (focus on cooperative and cooperative dependent sensors) enabling the operational use of security functions. Scope covers the sensor based enhancement of threat detection capabilities, performance assessment and identification of detection forwarding mechanisms.

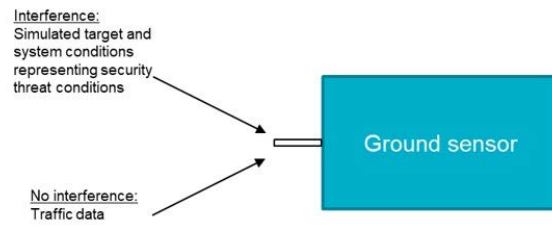


Figure 3: Base Test Scenario

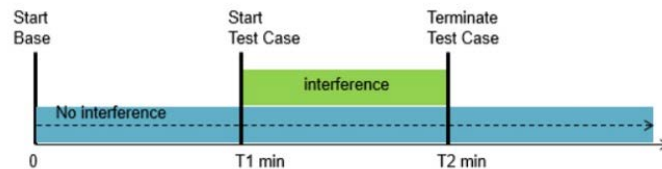
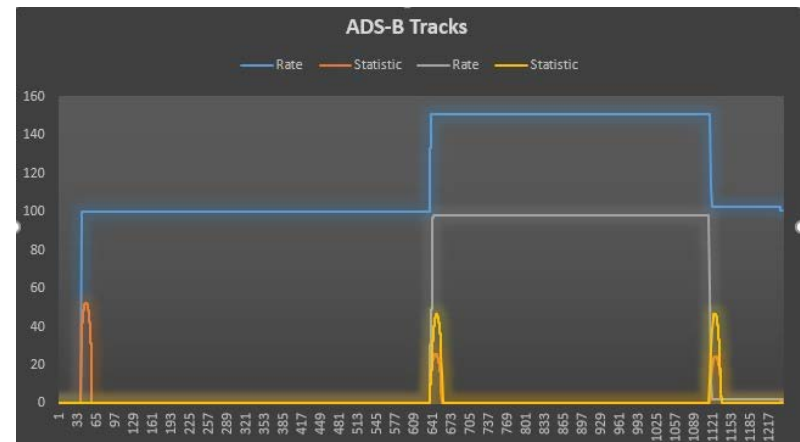


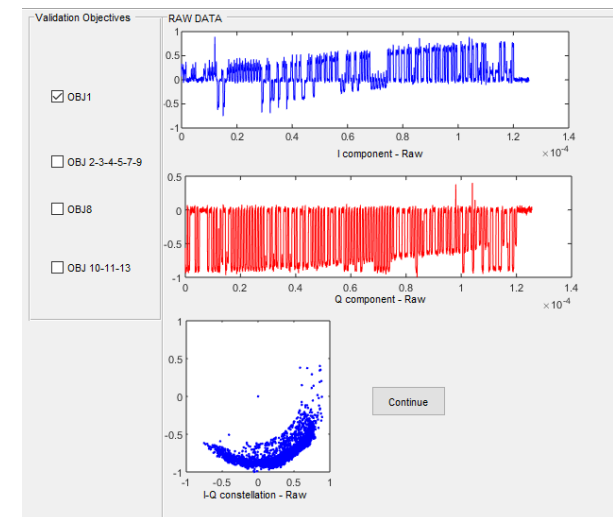
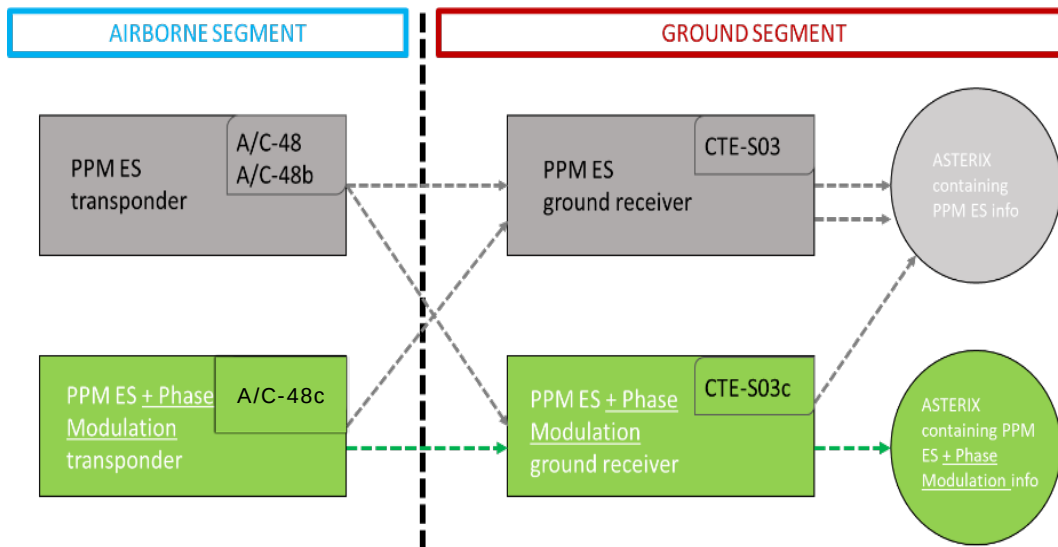
Figure 4 Interference introduction into the system



Cross-cutting issues (tech & non-tech.)



- **WP12 Phase Modulation – future ADS-B datalink.** Adding phase information to existing 1090MHz ES signals increases link capacity for different future uses .



Impact



- Development in the composite surveillance field are directly incorporated into standards.*

Composite and Security

These functionalities are incorporated as input in EUROCAE ED129 and ED142 standards for WAM & ADSB through EUROCAE WG51. Also new Mode S specification by Eurocontrol will incorporate composite surveillance functionalities.

Phase Modulation

Will be incorporated in future Transponder standards ED102.

PBS Monitoring Tools

Will demonstrate compliance with existing standards.



Thank you !



Enabling aviation infrastructure

GATEMAN project: "GNSS navigation threats management on-board of aircraft"

Elena Simona Lohan
Tampere University, Finland

Outline

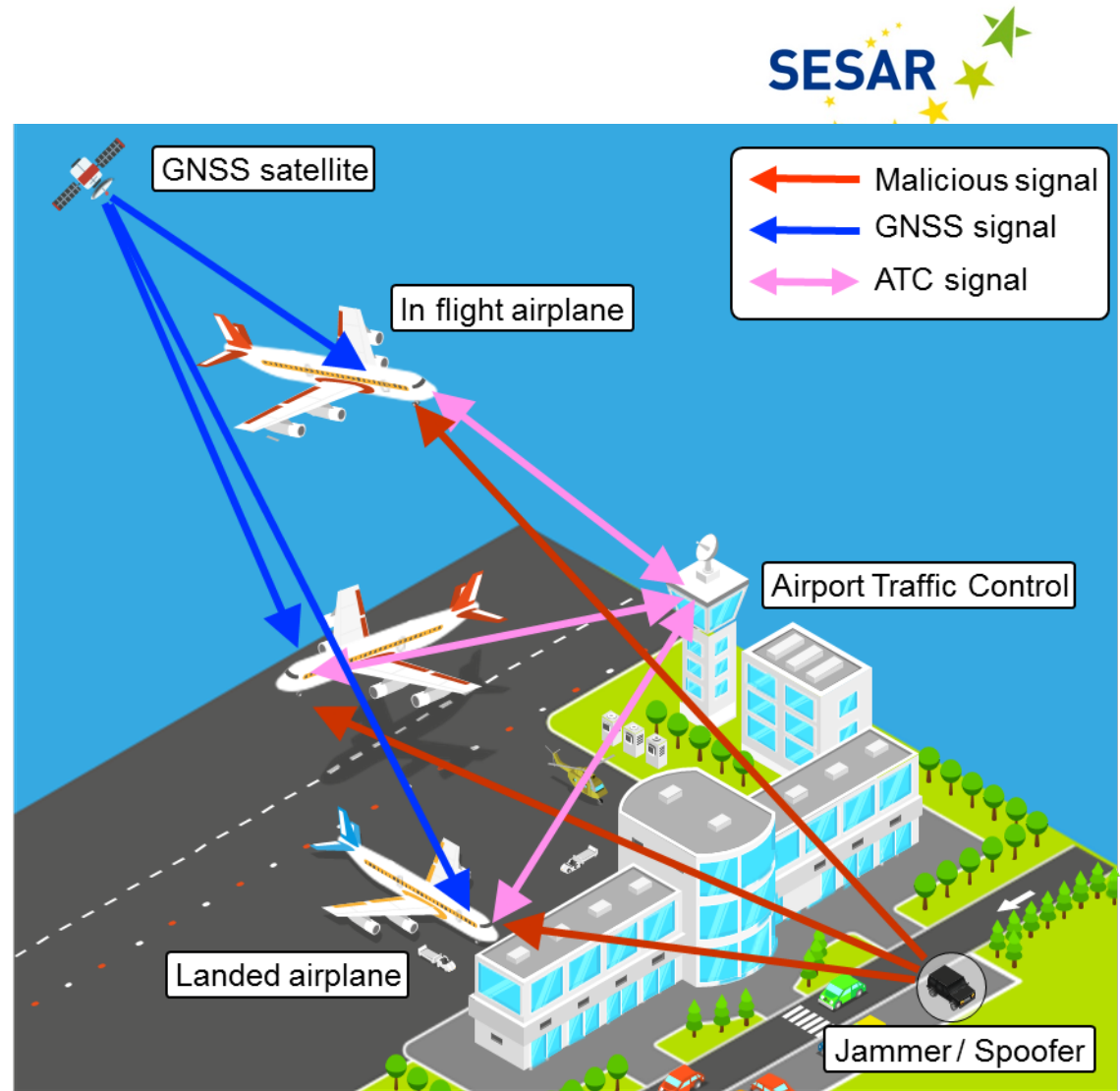


- ***Motivation***
- ***Overview of threat management solutions***
- ***Scientific & technical goals of GATEMAN project***
- ***Main achieved results***
- ***Impact and next step developments***

Motivation

*Interference threats in aviation: **47 times increase** over four past years:*

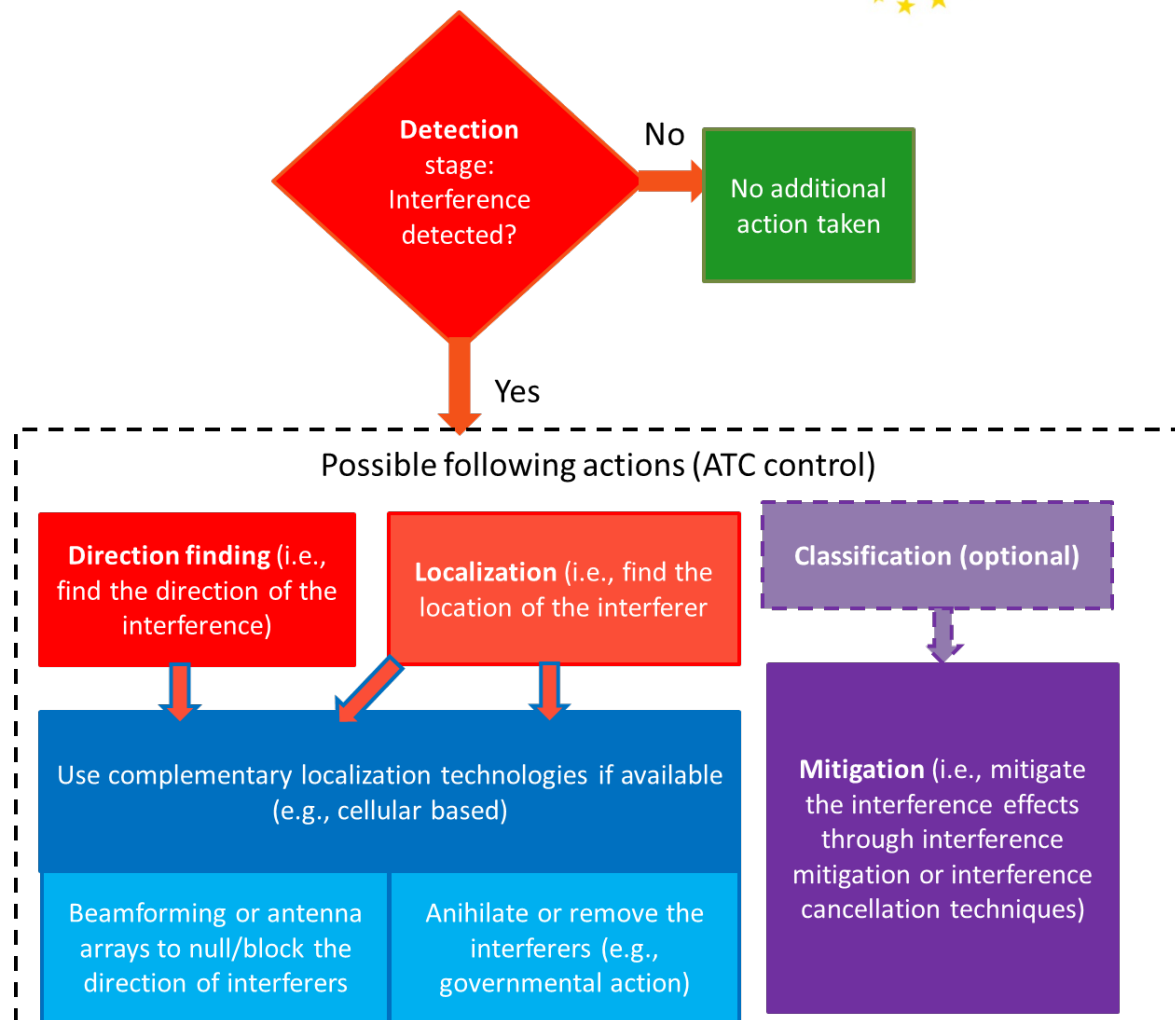
- From 17/year (2014) till 815/year (2018),
- **Mainly due to jamming & spoofing** (Eurocontrol Voluntary ATM Incident Reporting of GPS outages)



Overview of threat management solutions



- *Better **interference counter-measures***
- *Complementary/ alternative **navigation & tracking solutions**, e.g., based on **future 5G signals***



Scientific & Technical goals



Goals / Mitigation Barriers

- *Novel concept for GNSS interferences management.*
- *Detection and localization of jamming and spoofing on-board the aircraft, based on existing aircraft equipment*
- *Application of 5G ground cell stations networks as Alternative Position, Navigation and Timing technology.*
- *Application of “spoofing monitoring” to mitigate the effects of spoofing*

Hypotheses

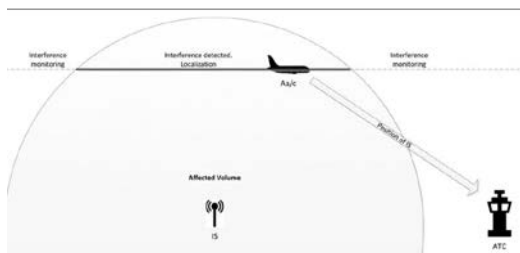
- *Use the existing aircraft equipment (minimize retrofit)*
 - *Omnidirectional GNSS antennas.*
 - *GNSS antennas on top of the fuselage (used for navigation).*
 - *3 GNSS antennas (existing aircrafts are equipped with 2).*
- *On-ground source of interference; single source; static/quasi-static*

Concept for interferences management

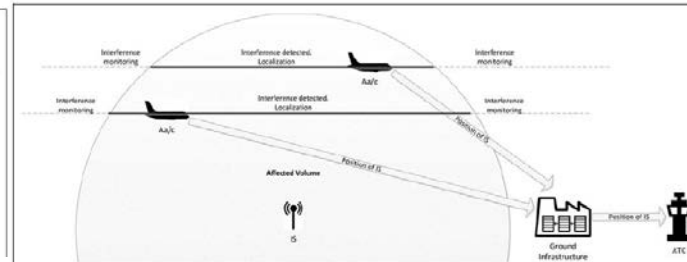


Proposed Modes of Operation:

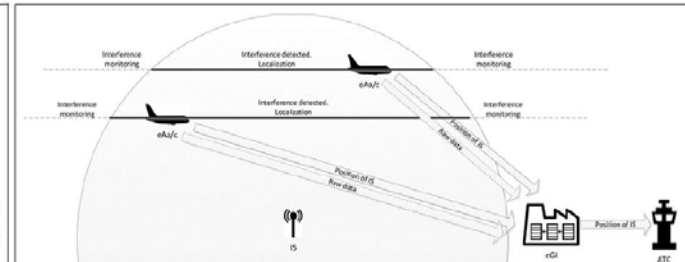
D&AL



D&CL



D&eCL



Mode	Airborne (Data Processing)	Airborne (Data Link)	Ground Infrastructure
Detection & Autonomous Localization (D&AL)	Same	Low-rate	None
Detection & Collaborative Localization (D&CL)			Basic
Detection & Enhanced Collaborative Localization (D&eCL)		Low-rate & High-rate	Improved

The main achieved results (1 / 2)

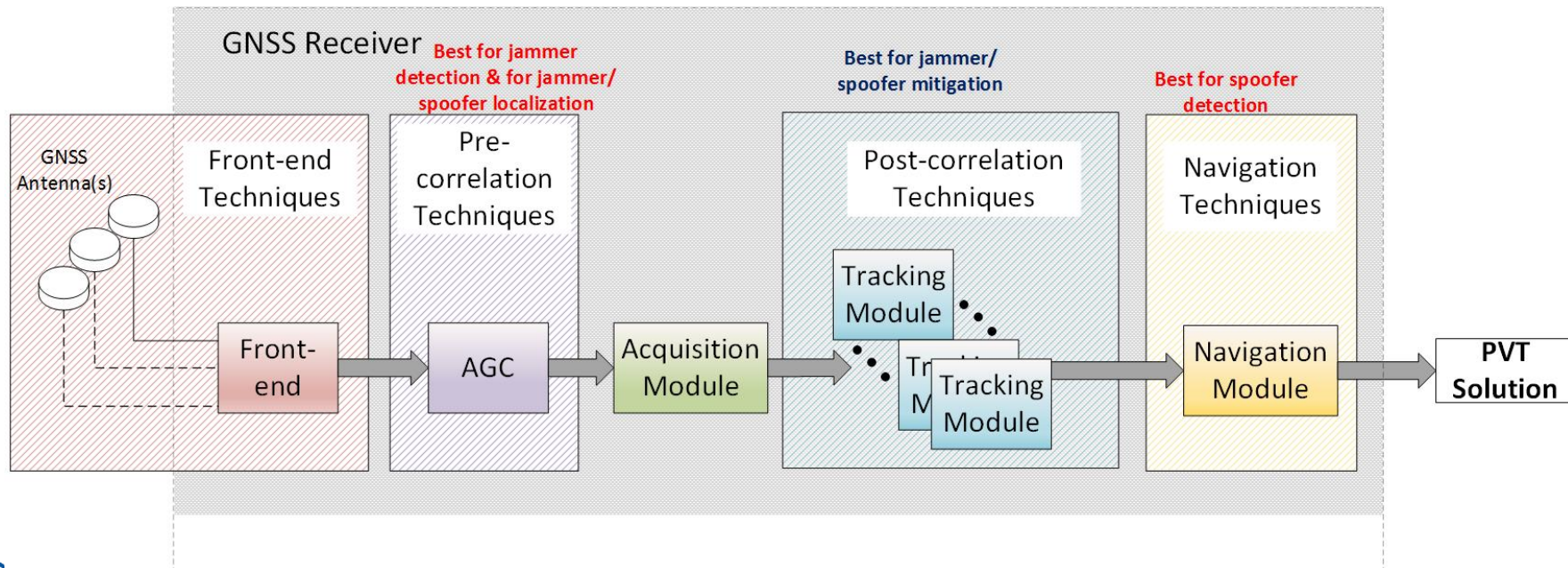


Investigated algorithms

11 Jammer detectors
3 Spoofing detectors
3 jammer localization &
direction finding algorithms

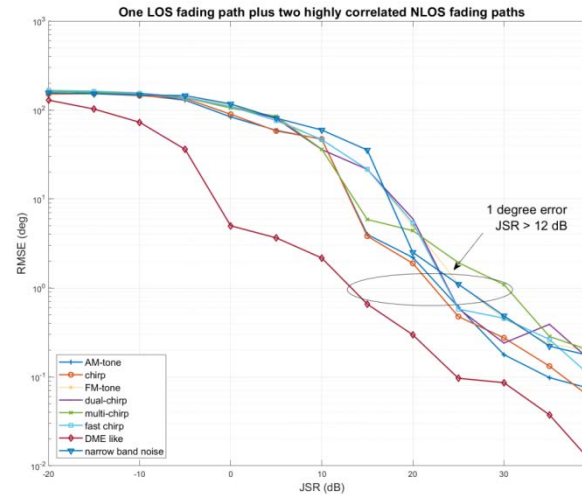
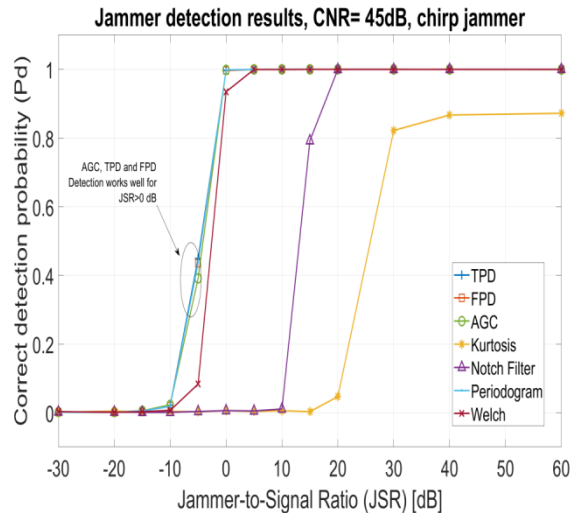
Findings

- **AGC and time/frequency power detectors** for the jammer detection (1 antenna)
- **Sum of Squares(SoS) / Dispersion Of Double Differences (D^3)** dual-antenna detector for the spoofing detection (2 antennas)
- **AoA** for both jamming and spoofing (3 antennas to avoid ambiguities)



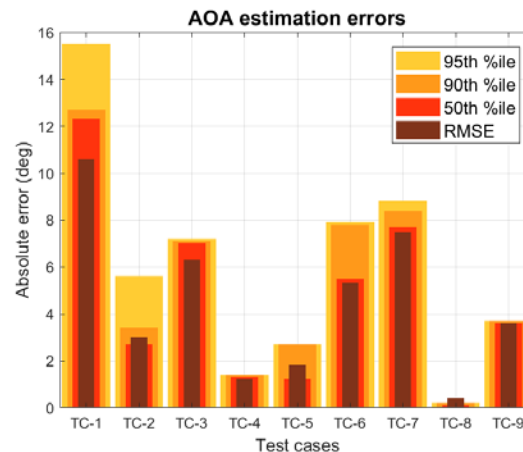
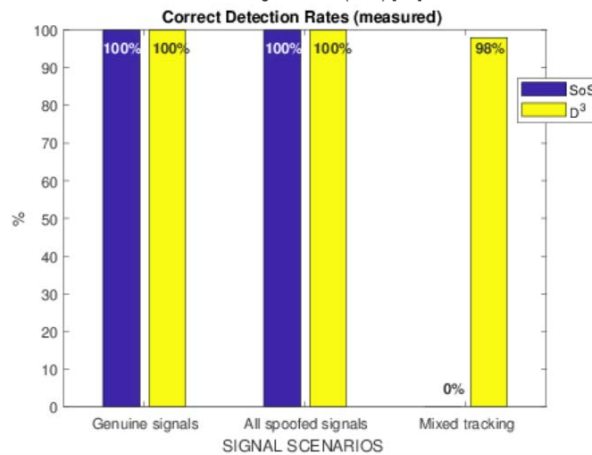
The main achieved results (2 / 2)

Snapshot results



Jamming

In-lab validation data in open access:
<https://zenodo.org/record/2654322> and
<https://zenodo.org/record/2537055>



Spoofing

Accuracy below 7.5 degrees in all-but-one cases; accuracy below 4 degrees in 50 % of cases

Challenges



- *Real-field validation of results*
 - **Jamming illegal in EU**
- *Multi-antenna needed on-board of aircraft for accurate spoofing detection and interference localization/direction finding*
 - **Interference with other wireless on-board equipment must be taken into account**
- *Alternative solutions have long-term feasibility*
 - **5G networks not yet mature;**
 - **Theoretical performance of 5G positioning solutions might be hard to achieve in realistic scenarios**

Impact



- **Reducing the time in detecting and localizing** interfering sources with on-board solutions
- **Reducing the number of GNSS outages** through threat management
- **Cost effectiveness/** no or minimal additional infrastructure



Robustness & safety

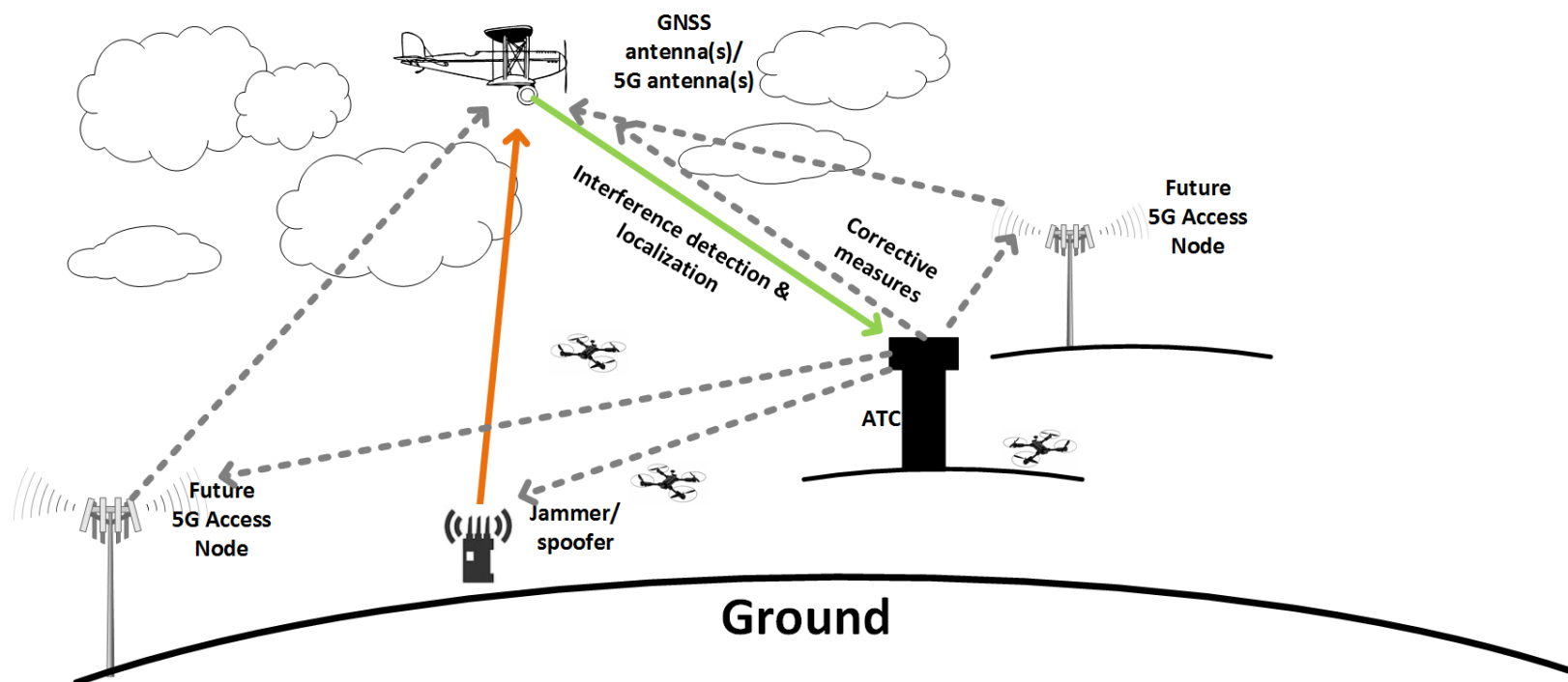
List of publications

1. 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
2. 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", to be re-submitted after revisions to IEEE Communications Surveys and Tutorials
3. 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.
4. 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.

Next steps in development



- *Using the Ultra Dense 5G Networks for 5G positioning as a complementary solution in harsh environments*
 - **Mostly likely suitable for urban/sub-urban scenarios & low/medium -altitude aircrafts**



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Thank you !

