EUROPEAN SPACE WEEK

ONLINE EDITION

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# GALILEO-BASED TIMING RECEIVER FOR CRITICAL INFRASTRUCTURES: THE GIANO PROJECT

User Consultation Platform 2020

**Livio Marradi**

Organised by:

European Global Navigation Satellite Systems Agency

European Commission

Under the auspices of:

eu2020.de

EU Space Programme:

Copernicus

EGNOS

GALILEO

# OUTLINE

1. INTRODUCTION
2. TIMING USER NEEDS
3. GIANO TIMING PLATFORM
4. TIMING SERVICE ROBUSTNESS
5. CALIBRATION & VALIDATION

# THE GIANO PROJECT

## Project Context

- **Growing concern regarding** the possibility of **jamming and spoofing GNSS** signals, with the consequent **disruption of Critical Infrastructures services** that rely heavily on GNSS timing to operate

## Objectives

- **Bring Galileo** and EGNOS-driven **innovation to GNSS-based Timing and Synchronization** (T&S) **domain**
- Demonstrate that a Galileo-based timing receiver is a suitable solution to **improve resilience and robustness** to RF threats at a reasonable cost
- **Fulfil specific T&S needs** (accuracy, traceability, availability, continuity) of Energy, Telecom, Finance users and of heterogeneous timing applications
- Realise a **Galileo-based timing platform** to TRL7

# GIANO CONSORTIUM

**Thales Alenia Space** in Italy has plurennial experience in GNSS systems and in development of GNSS-based products for ground and space applications.

**Business Integration Partners** is involved in stakeholders interface, dissemination activities and business plan, providing its experience in strategic analyses and business modelling.

**PIKTime Systems** is experienced in time-based products and services development and is advisor on precise time, scales and design of time & frequency algorithms.

**Space Research Center** of the **Polish Academy of Science** has strong heritage in timing systems, has participated to several European scientific and navigation programmes.

**DEIMOS Engenharia** is largely involved in GNSS projects with deep knowledge and experience in SW and algorithms development for GNSS-based equipment.

# TIMING NEEDS AS INDICATED BY USERS

## User Consultations

- Revealed high interest in **accuracy, integrity** and **robustness**
- However, actors still perceive **security aspects unrelated to T&S devices**

| | | |
|---|---|---|
| Accuracy | | 91% *of the users* |
| Integrity | | 64% *of the users* |
| Robustness | | 60% *of the users* |

### Energy

*Primary*
Accuracy Integrity

*Secondary*
Availability Continuity

### Telecom

*Primary*
Accuracy
Robustness Continuity

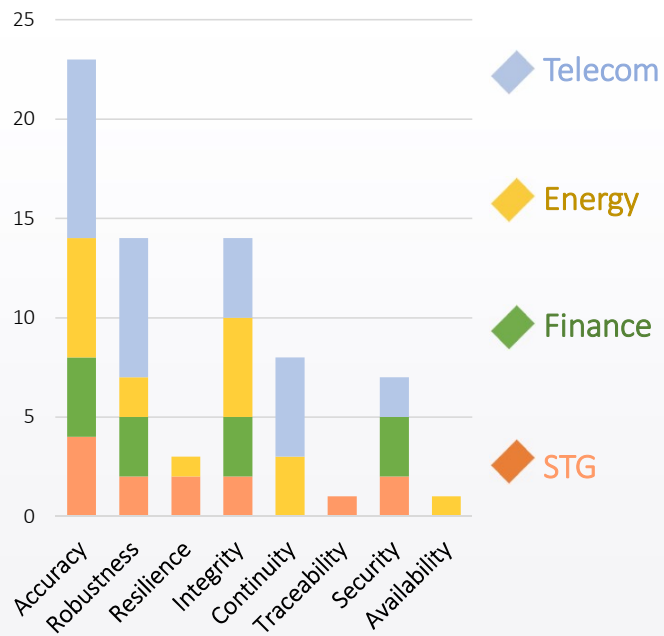
*Secondary*
Integrity Security

### Finance

*Primary*
Accuracy

*Secondary*
Robustness
Integrity Security

*Main features pointed out by Users*



# TIMING NEEDS SCENARIO & EVOLUTION

## Primary Target Group

Timing Scenario Evolution shows tighter accuracy requirements in all applications:

- **Energy:** more precise fault location
- **Telco:** boost 5G
- **Finance:** enable High-Frequency Trading

## Secondary Target Group

**Rail** and **Aviation** T&S needs are less demanding in terms of accuracy but becoming important in terms of integrity and safety

| | *Application* | *Current needs* | *Future needs* |
|---|---|---|---|
| **ENERGY** *1 ms to 50 ns* | PMUs (*protection & control*) | 1 µs | 50 ns |
| | *Timestamping* | 1 ms | - |
| | *Differential Protection* | 100 µs | - |
| **TELECOM** *10 µs to 10 ns* | SATCOM | **100 ns** | - |
| | PMR | 10 µs | - |
| | 5G (CA *intra-band contiguous*) | 130 ns | **10 ns** |
| **FINANCE** *1 ms to 100 ns* | *Transactions* (in EU) | 100 µs | 1 µs |
| | *High-Frequency Trading* (HFT) | **100 ns** | - |
| | *Bank* | 1 ms | - |
| **STG** *500 µs to ps* | Rail (*NTP for synch*) | 500 µs | - |
| | Aviation (*radar data & audio*) | 1 µs | - |
| | Research (*time generation*) | **1 ns** | **ps** to **fs-level** |
| | *Timing Distribution* | **0.5 -10 ns** | - |

# WHICH BENEFITS FROM GALILEO & GNSS?

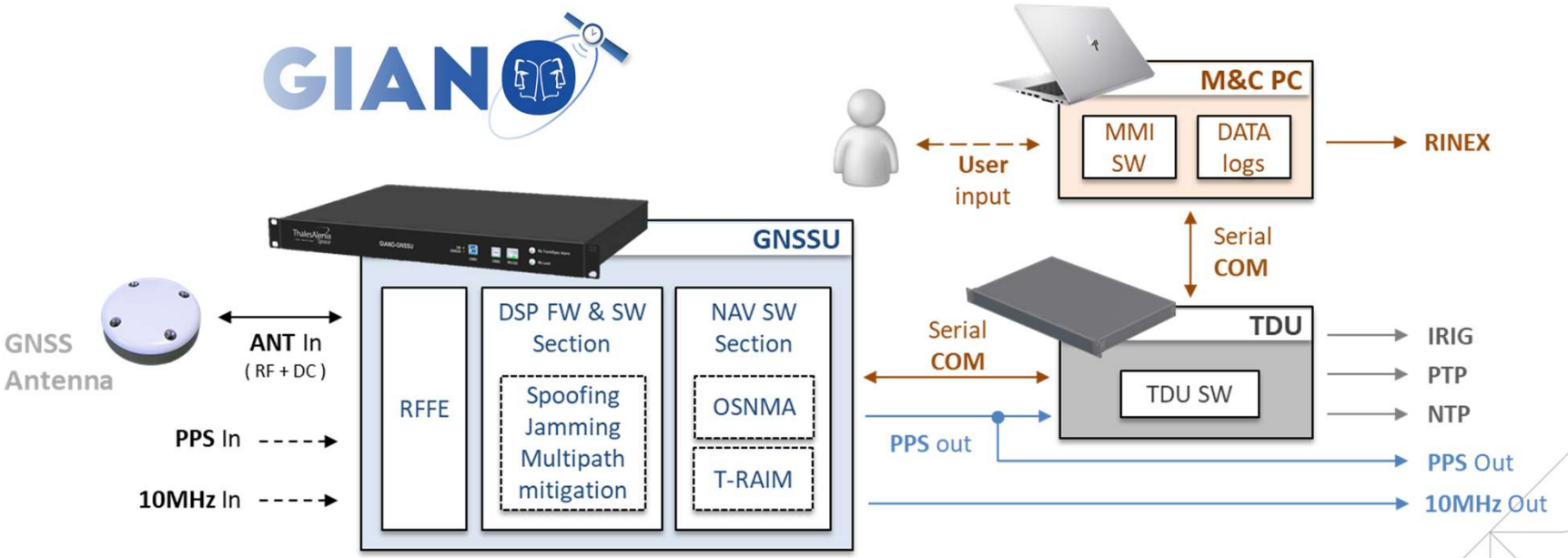
## Benefits

- Increase **robustness against spoofing**, thanks to its authentication feature
- Increase **timing service availability**, when using 2 constellations (GAL+GPS), increasing the number of satellites
- **Provide a Common standardised time service**

## Added Value

- **Time Integrity**: confidence and performance assessment of timing information disseminated by the system
- **Trusted Time Distribution**: dissemination of *UTC* time and frequency over the Internet, enabling remote assessment of the client clock synchronization
- **Certified Time Steering and Monitoring**: disseminating precise and accurate time using multi-GNSS-based Time transfer and providing real-time monitoring and certification
- **Robust Accurate Time**: offering robustness against GNSS signals, system failures (incl. jamming and spoofing) and against failures or attack on the communication network

# GIANO PLATFORM OVERVIEW




** GIANO is a **TRL7 System Prototype** demonstrator in operational environment*

# GIANO TIMING PLATFORM: KEY FEATURES

## GNSS Processing

- **Multi-GNSS** and **Combined solution** capability (**GPS + Galileo + EGNOS**)
- **Flexibility** and **Configurability** from single to multi-frequency (**L1/E1, L5/E5a**)
- **Tunable bands** with **innovative Direct-Sampling** approach and **Digital Down-Conversion**
- Synchronization with **Galileo System Time** (GST), **GPS system Time** (GPST), **UTC**

## Improved Timing Robustness

- **Jamming** & **Spoofing** detection / mitigation capability
- Use of **Galileo OS-NMA authentication** service
- Compatibility with **EGNOS corrections**
- **T-RAIM** algorithm for time solution **integrity** (single or multi-constellation based)
- **Accurate Time-Steering** and **Holdover** automatic switch
- Future evolution to periodic **Auto-Calibration** capability

# TIMING SERVICE ROBUSTNESS: SYNCHRONIZATION

## Time Steering

### Improved timing signal continuity & availability

- Steering to UTC and smooth transition between GST and GPST
- No transitory or jumps due to GNSS switch
- Convergence & synch recovery after holdover

### Early malfunction and anomalies detection

- Easier maintenance (FW/SW approach)
- On-demand or continuous integrity monitoring & notification

### Service-oriented implementation in critical infrastructures

- Capability for timing service performance monitoring against Service Level Agreements



# TIME STEERING: PRELIMINARY PERFORMANCE

**Clock Drift**
approx. ±0.13ns/s (max)

*Time-Only Solution*
*WLMS PVT Solution*

**Clock Bias**
approx. ±5ns (max)

*Time-Only Solution*
*WLMS PVT Solution*

# TIMING SERVICE ROBUSTNESS: RF ENVIRONMENT

## RFI Detection & Mitigation

### Antenna level

- RHCP Gain roll-off
- Front-End (BPF bandwidth, LNA, …)

### Pre-correlation level (FPGA)

- AGC
- Digital Pulse Blanking
- Digital Filtering

### Post-Correlation level (DSP)

- Observables based (C/N0, CMC, etc.)

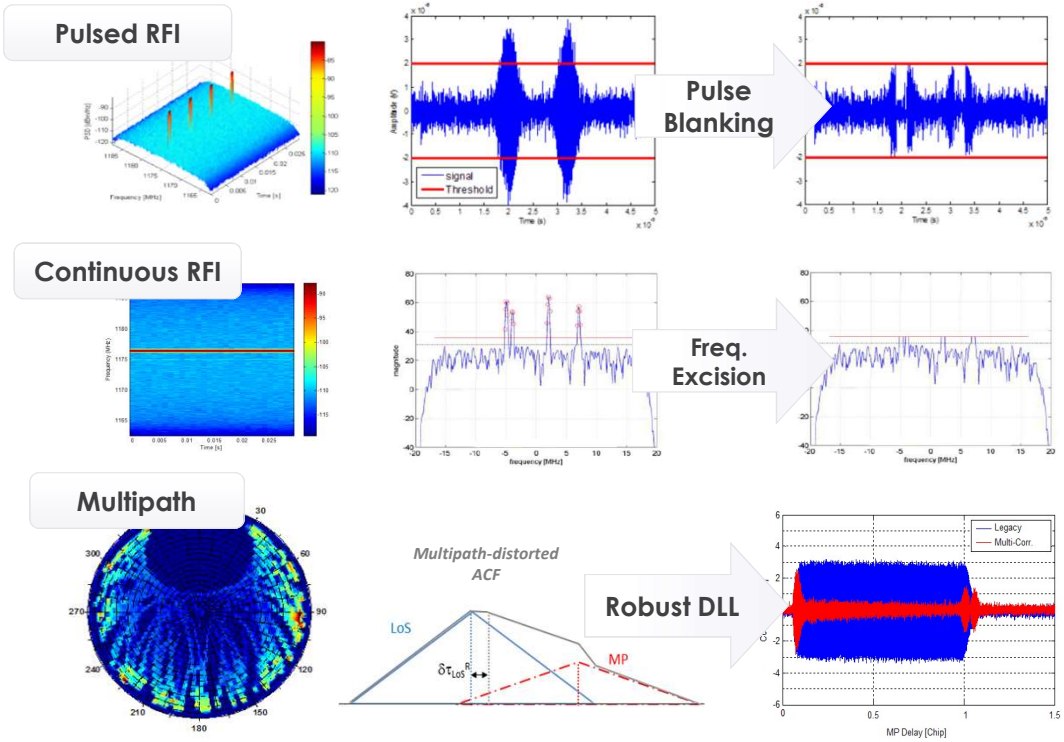
## Multipath Detection & Mitigation

### Antenna level

- RHCP-LHCP D/U ratio

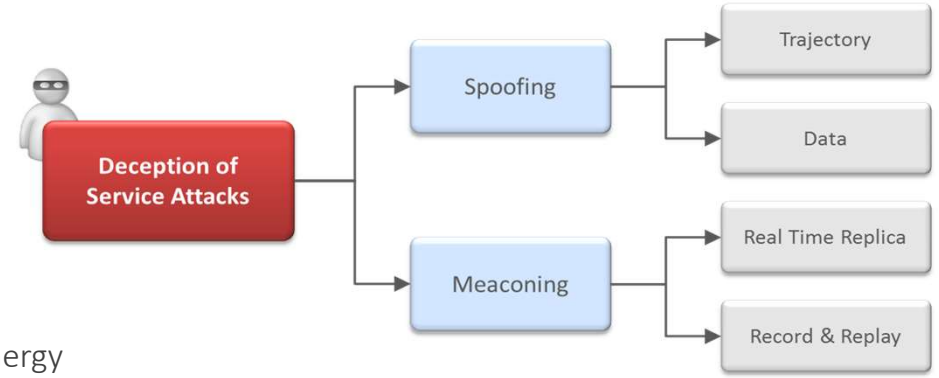
### Post-Correlation level (DSP)

- Multi-Correlator Robust DLL
- Observables based (C/N0, CMC, etc.)



# TIMING SERVICE ROBUSTNESS: ANTI-SPOOFING

## Spoofing Detection & Mitigation




### Pre-correlation level

- AGC Monitoring

### Acquisition / Correlation level

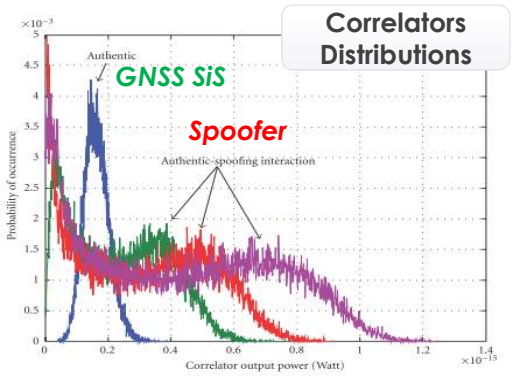
- Correlators Output Statistics (Center of Mass & Total Energy

### Tracking / Observables level

- Observables consistency check

### System level

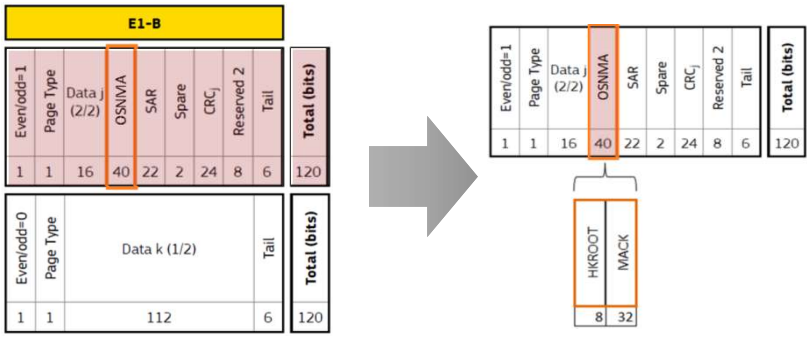
- Navigation Message Authentication (OSNMA)



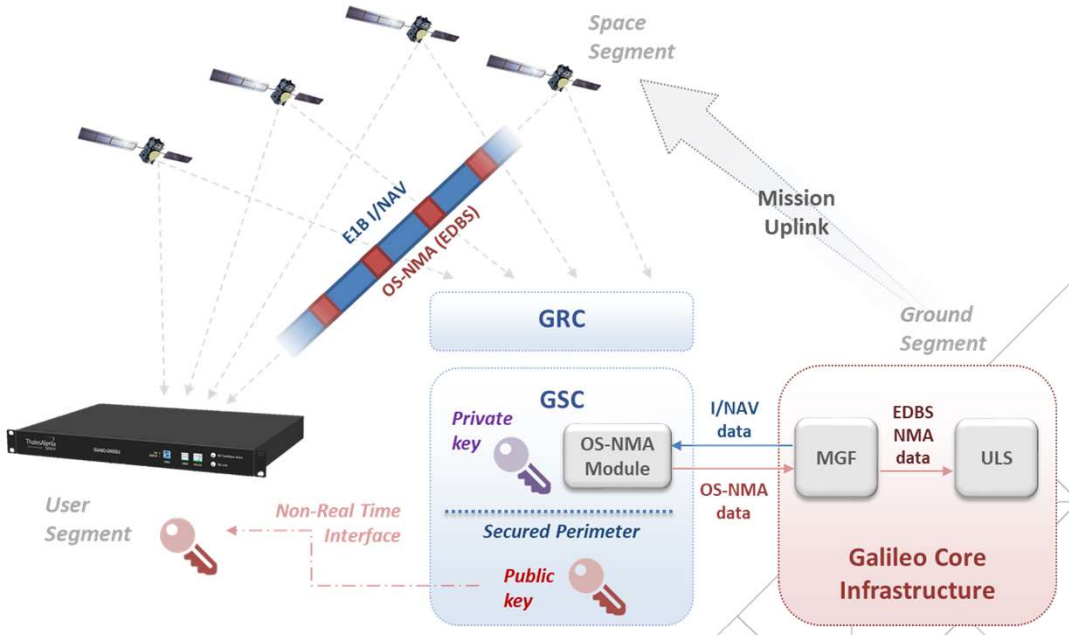
# TIMING SERVICE ROBUSTNESS: OSNMA

## Open Service Navigation Message Authentication

- I/NAV Galileo Message is broadcasted in E1B




- OSNMA is based on TESLA protocol
- Anti-replay attacks protection based on OSNMA unpredictable symbols



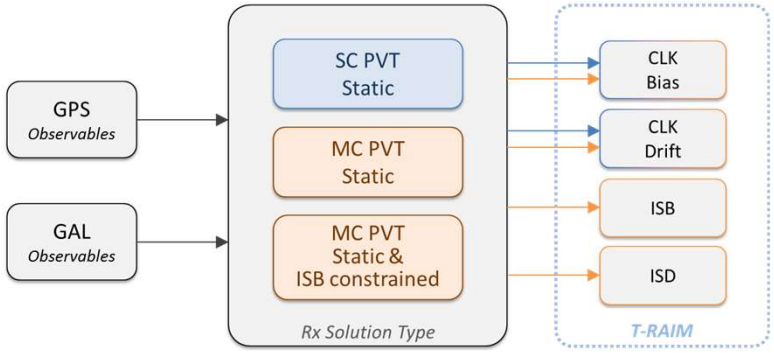
# TIMING SERVICE ROBUSTNESS: T-RAIM

## Time Solution Receiver Integrity Monitoring

For a typical timing receiver, **position** is **known** and **static** (i.e. only clock bias & drift to be estimated)

**Redundancy** can be exploited to:

- Increase **timing solution reliability**
- **Detect inconsistencies** among GNSS observables
- **Identify outliers** in measurement set




Availability of **several GNSS constellations** provides a significant opportunity to further **improve T-RAIM** performance

**Inter-System Bias** (i.e. GGTO) and **Drift** must be carefully handled to avoid phase discontinuities in case of sudden loss of one of the two GNSS constellations

# CALIBRATION

In-factory **calibrated equipment** is subject to **degradation** and needs to be **periodically re-calibrated**.

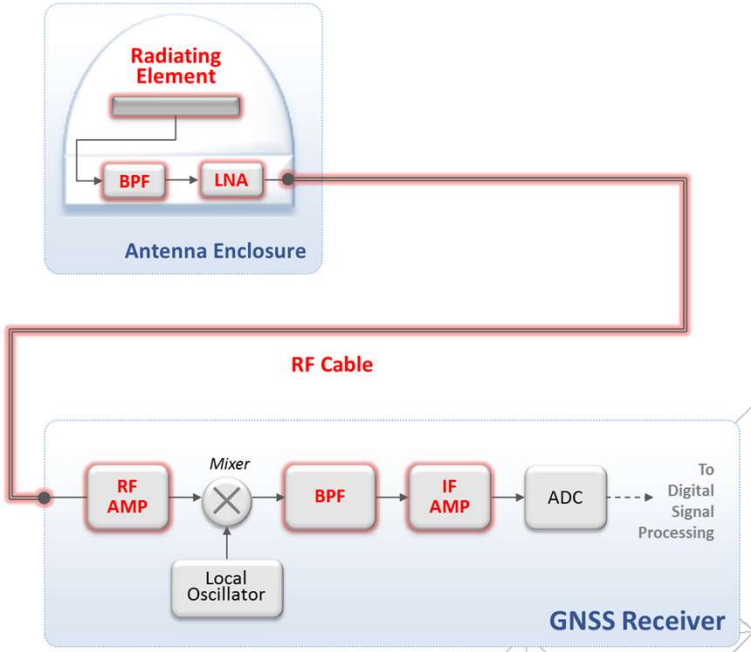
Degradation is caused mainly by:

- **Aging** of components (i.e. random changes w.r.t. initial operating points)
- **Retrace** (i.e. steadiness of delay measurements after power-cycles)
- **Operating conditions** (typically different from calibration laboratory ones)

**Calibration** is typically performed in **two ways**:

- **Absolute**: delays measured w.r.t RF timing marker test signal (before / after antenna radiating element, prior to filters and LNA)
- **Relative**: delays measured against previously calibrated reference receiver chain.

Built-in **auto-calibration** techniques have been investigated for final product implementation.




** Items in red introduce a substantial delay*

# VALIDATION APPROACH

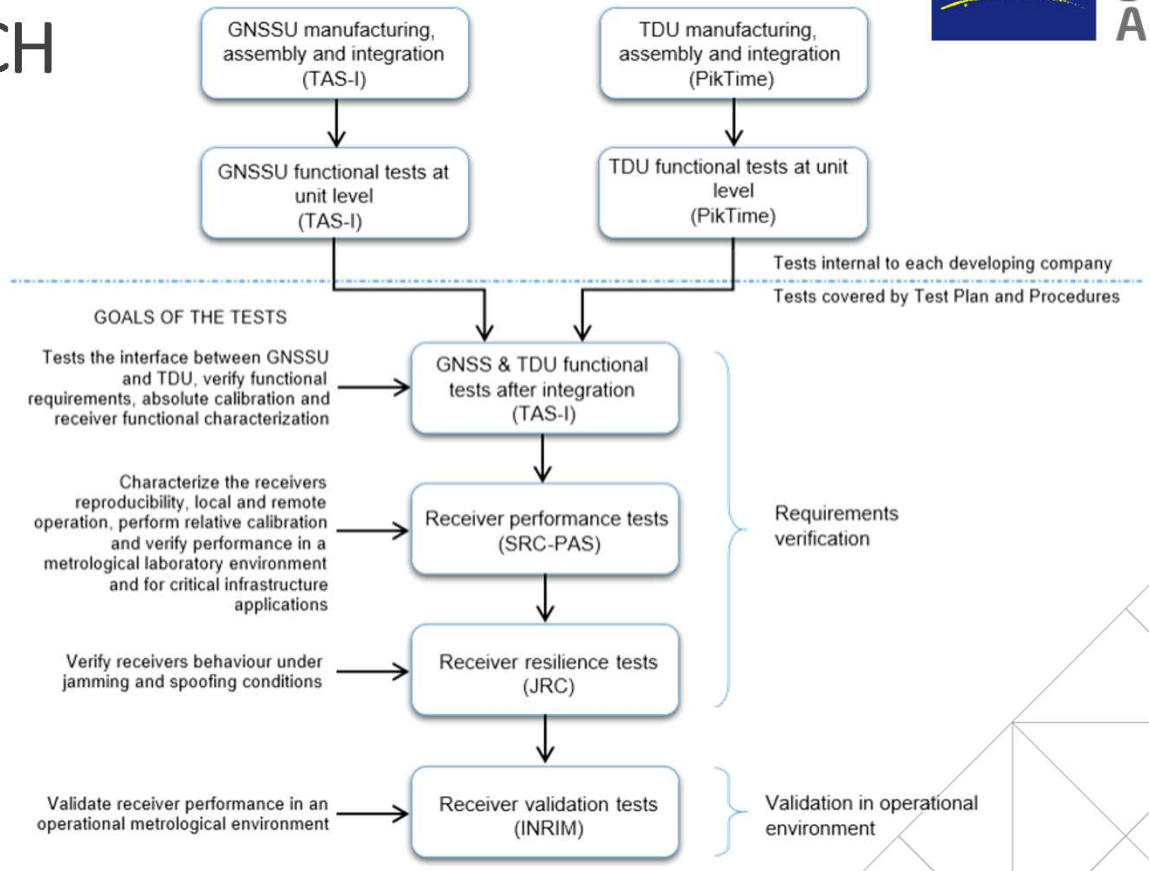
Extensive **validation test campaign**, conducted in **four phases**, through involvement of Team's experts and support of European laboratories

February 2021 — 1 — ThalesAlenia Space

March 2021 — 2 — CBK

May 2021 — 3 — European Commission Joint Research Centre

May 2021 — 4 — INRiM Istituto Nazionale di Ricerca Metrologica

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# STANDARDIZATION & CERTIFICATION

**No unique standard** applicable to GNSS timing receivers

Existing standards are more related to **data format** & **I/F**:

- Standards applicable to data format of high-end receivers, such as the **CGGTTS** format (BIPM)
- Ubiquitous standard used for timing (PPP), i.e. **RINEX**
- Receivers used in critical infrastructures generally outputs time coded data in **IRIG-B** format, with variations for power grid operators conforming to **IEEE C37.118** Standard (recently superseded by **IEEE Std C37.118.1** and **IEEE Std C37.118.2**)
- Financial transactions conform to recent **MIFID-II** directive

Timing services **certification** is the **added-value** making service more appealing to users

An **approach to certification** of a GNSS timing receiver could consider as a minimum:

- Receiver **overall performances assessment** under operating conditions (e.g. jamming, spoofing, etc.)
- **Calibration** by a **certified laboratory** (possibly receiver auto-calibration during operation)
- **Remote monitoring** of overall performance may be required by specific applications

deimos elecnor group · CBK · PIK Time Systems · bip. · ThalesAlenia Space a Thales / Leonardo company

# Linking space to user needs

How to get in touch:

European GNSS Agency

**www.GSA.europa.eu**

EGNOS-portal.eu

GSC-europa.eu

UseGalileo.eu