ThalesAlenia Space
a Thales / Leonardo company

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European Global Navigation Satellite Systems Agency

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GALILEO-BASED TIMING RECEIVER FOR CRITICAL INFRASTRUCTURES ROBUSTNESS

International Timing and Sync Forum
Brighton (UK)
November 7th, 2019

ThalesAlenia Space · Bip · PIK Time Systems · CBK · deimos elecnor group

OUTLINE

PROJECT TEAM /// KEY ROLES

Consortium is composed by companies, institutions and experts with background and competence in timing applications:

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

Business Integration Partners is involved in the consortium for user groups interface, dissemination activities, 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 software 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 a company largely involved in GNSS projects and with deep knowledge and experience in SW and algorithms development for GNSS-based equipment.

GALILEO-BASED TIMING RECEIVER FOR CRITICAL INFRASTRUCTURES ROBUSTNESS

GIANO Project Context

" A **growing concern** exists regarding the possibility of **jamming** and **spoofing** GNSS signals, with the consequent **disruption of critical services** and infrastructures that rely heavily on GNSS timing to operate … "

Project Drivers

1. Fulfillment of specific **T&S needs** for **Critical Infrastructures** (health, safety, economic & social welfare).

2. Provision of **robust timing services** for critical users belonging to **Energy**, **Telecommunications**, **Finance** domains.

3. Promotion of **Galileo & EGNOS** use for infrastructures protection, improving GNSS-based timing solutions resilience to RF environmental threats.

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OUTLINE

1 INTRODUCTION

2 TIMING USER NEEDS

3 GIANO TIMING PLATFORM

4 TIMING SERVICE ROBUSTNESS

5 GIANO CALIBRATION & VALIDATION

TIMING USER NEEDS /// STAKEHOLDERS POINT OF VIEW

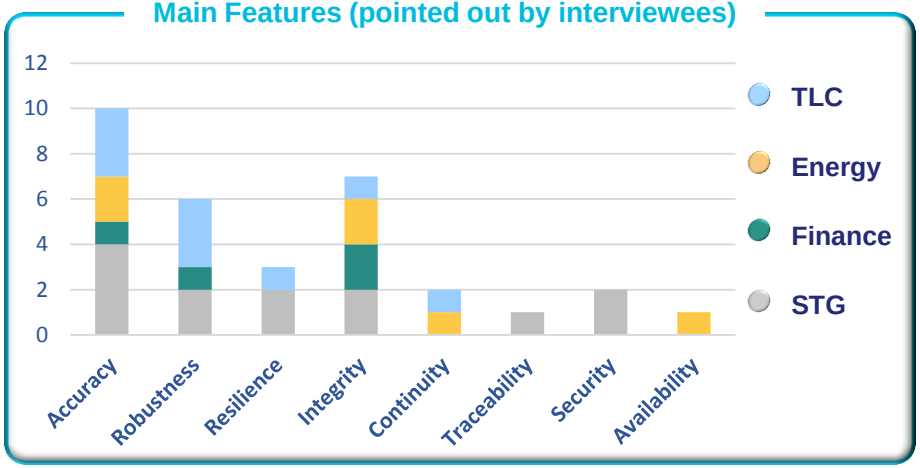
Stakeholders feedbacks revealed a high interest in **accuracy, integrity** and **robustness** features:

- **Accuracy** — **91%** *of the interviewees*
- **Integrity** — **64%** *of the interviewees*
- **Robustness** — **54%** *of the interviewees*

Continuity of service & **availability** features are perceived as **less important**, due to the fact that often redundant systems are used

Security, **continuity** & **availability** not perceived among fundamental features

Criticality due to **environmental threats** (jamming, spoofing, …)



Lack of correlation between security and **T&S devices** by Stakeholders point of view!

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TIMING USER NEEDS /// SCENARIO EVOLUTION

ENERGY applications

"between **ms** *and* **100 ns***"*

TELECOM applications

"between **ms** *and* **µs***"*

FINANCE applications

"around **100 µs***"*

Secondary Target Group

"between **500 µs** *and* **sub-ns** *level"*

	Current needs	Future needs
Energy	PMUs: **1 µs** Protection: between **1 ms** and **100 ns** Control: **1 ms** SDH: **1 ms**	PMUs: **50 ns** Protection & control: order of **1 µs** Process bus: between **ms** and **µs**
TLC	NTP for routing systems synch: **ms** Timing info source: between **ms** and **µs**	5G applications: **tens** of **ns** Synchronization: between **µs** and **100 ns**
Finance	NTP for synch: around **100 µs**	-
Rail	NTP for synch: around **500 µs**	-
Aviation	Time-stamp (radar data, audio record): **1 µs**	-
Research communities	National standard time generation: **1.5 ns** Time Dissemination: from **ms** to **ns**	National standard time generation: **fs-level** Time Dissemination: **ps-level**
Timing distribution operators	From **10 ns** to **500 ps** of uncertainty	-

See also: ***GSA Market Report***

See also: ***GSA Report on T&S User Needs***

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GIANO TIMING PLATFORM /// PROTOTYPE OVERVIEW

GIANO Timing Platform

COTS **ANTENNA**

designed to accommodate **L1/E1** & **L5/E5** bands

TIMING **RECEIVER**

composed by **GNSS Receiver** & **Timing Distribution** Module

M&C PC

control / monitoring SW for platform configuration and evaluation of KPIs

** TRL7 - System Prototype demonstrator in operational environment*

2019 - Design & Development | *2020 - Integration & Testing* | *2021 - Final Product*

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THALES ALENIA SPACE OPEN

OUTLINE

TIMING SERVICE ROBUSTNESS /// KEY DRIVERS

GNSS Processing

- **Multi-GNSS** and **Combined solution** capability (**GPS, Galileo** and **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 **GST** or **GPST**.

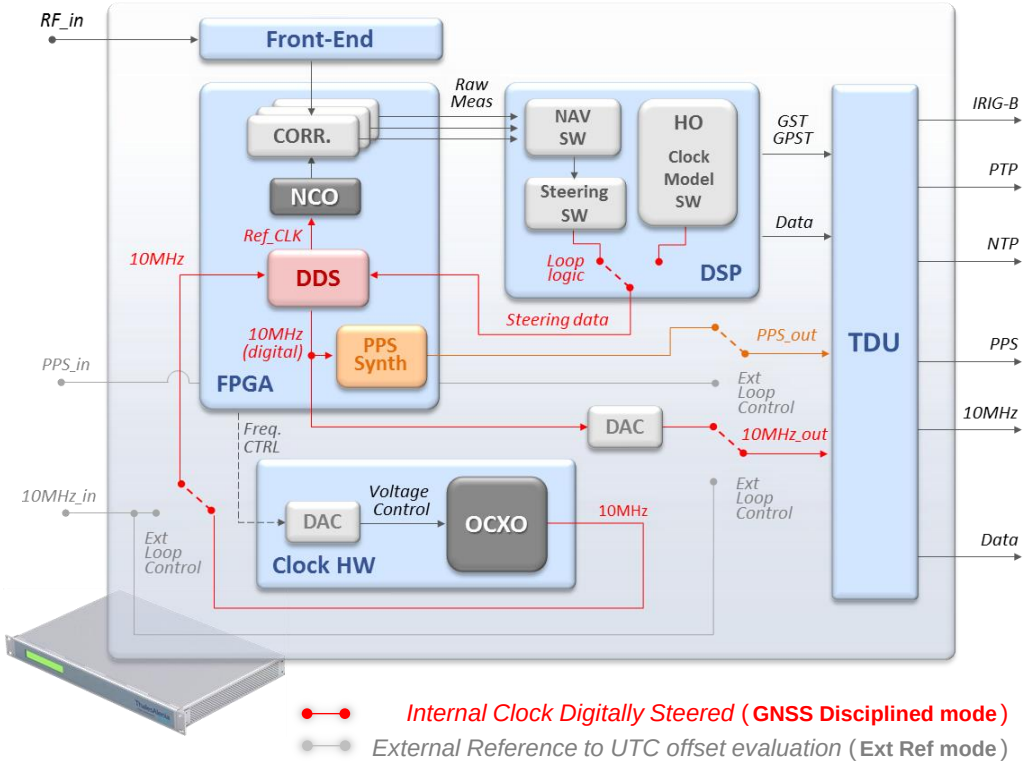
Improved Timing Robustness

- **Jamming** & **Spoofing** detection / mitigation capabilities.
- Use of **Galileo OS-NMA authentication** service.
- Availability of **EGNOS corrections**.
- **T-RAIM** algorithm for time solution **integrity** (single or multi-constellation based).
- **Accurate Time-Steering** and **Holdover** with transparent output towards user.
- Periodic **Calibration** or **Auto-Calibration** capability.

TIMING SERVICE ROBUSTNESS /// SYNCHRONIZATION

Digital Time-Steering Benefits

1. Improved timing signal **continuity** & **availability**:
   - No transitory / jumps due to lack of GNSS signals
   - Smooth convergence & synch recovery after holdover
2. Higher level of **configurability** (FW/SW based approach)
3. Solution **independent** from internal **clock** model
4. Early **malfunction** and **anomalies detection**:
   - Easier maintenance (SW based approach)
   - On-demand or continuous integrity monitoring & notification
5. KPIs for **Service Level Agreement monitoring**:
   - Synchronization predictions
   - A-posteriori synchronization evaluation
   - Autonomous time service performance monitoring



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TIMING SERVICE ROBUSTNESS /// RF ENVIRONMENT

Interference Detection & Mitigation

@ **Antenna** level**:**

- RHCP Gain Roll-off
- **Front-End** (BPF Bandwidth, LNA, …)

@ **Pre-correlation** level (i.e. in FPGA, based on RFI power before de-spreading)**:**

- **AGC**
- Digital Pulse **Blanking**
- Frequency **Excision**

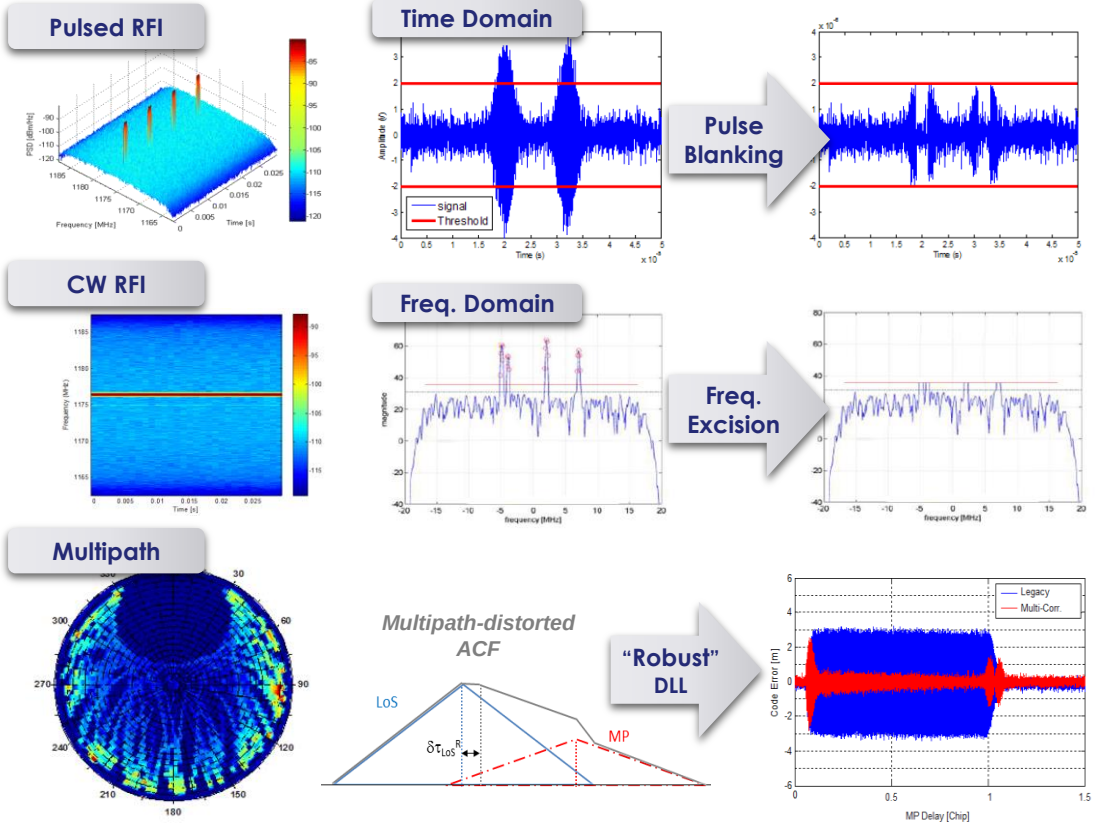
Multipath Detection & Mitigation

@ **Antenna** level**:**

- RHCP-LHCP **D/U ratio**

@ **Post-Correlation** level (i.e. in DSP)**:**

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



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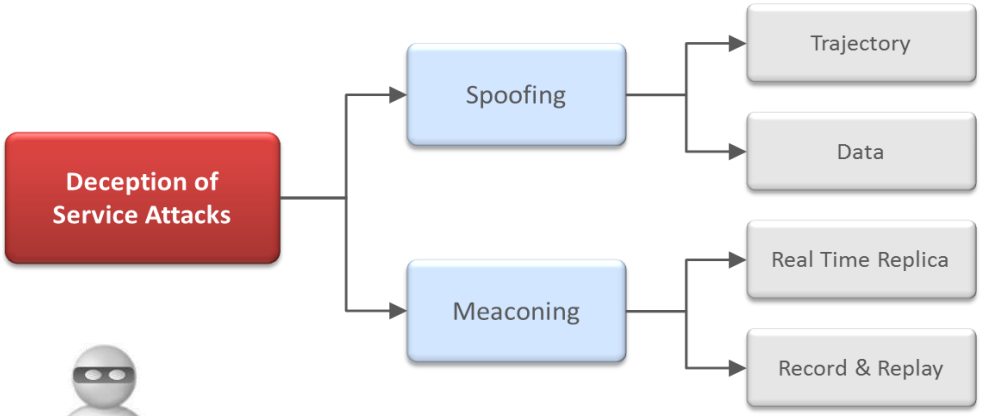
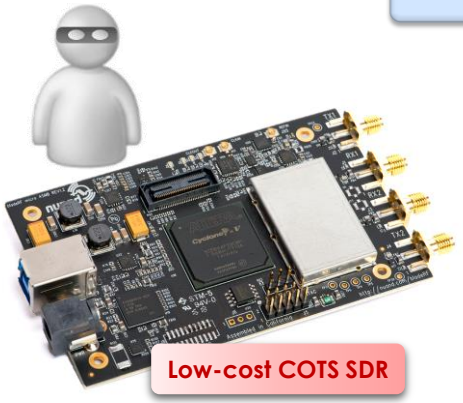
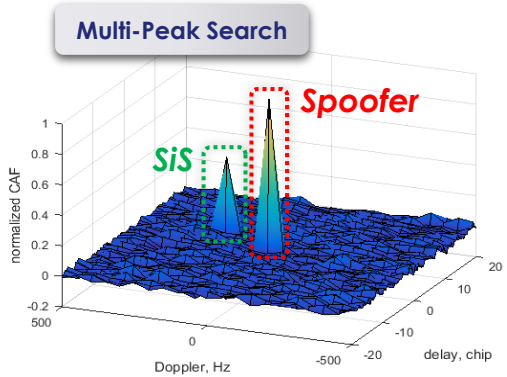
TIMING SERVICE ROBUSTNESS /// RF ENVIRONMENT

Spoofing Detection & Mitigation

- **Pre-correlation** level:
  - AGC Monitoring
- **Acquisition / Correlation** level:
  - Multi-Peak Search
  - Centre of Mass & Total Energy
- **Tracking / Observables** level:
  - Doppler / code delay rate consistency check
- **Navigation** level:
  - Anti-Spoofing RAIM
- **External Aiding / System Based** level:
  - Navigation Message Authentication







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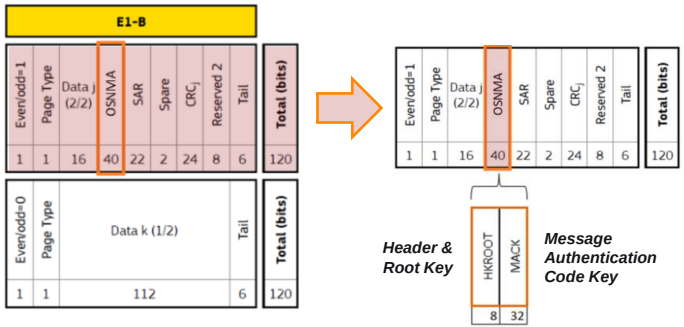
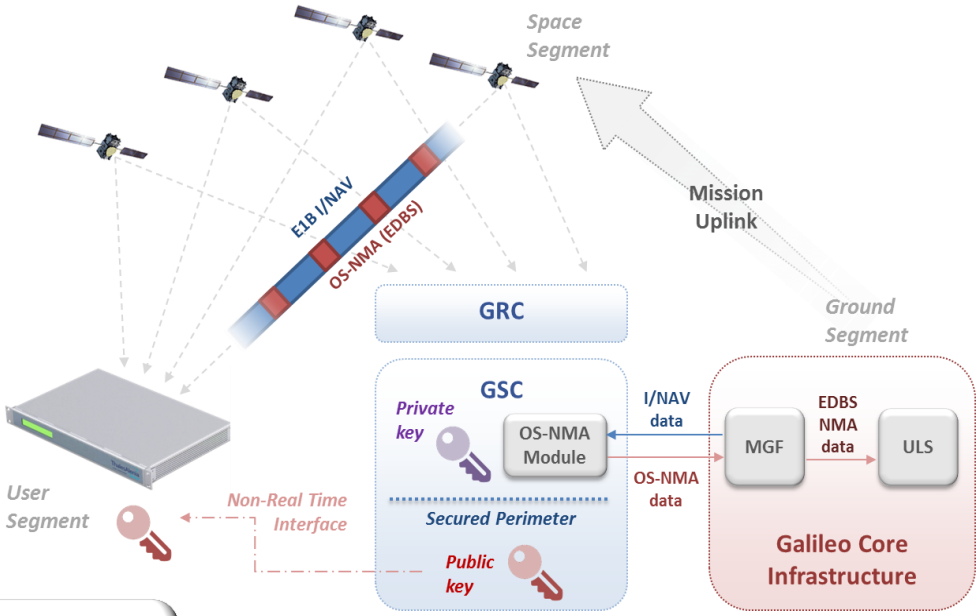
TIMING SERVICE ROBUSTNESS /// AUTHENTICATION

Open Service Navigation Message Authentication (OS-NMA)

- **I/NAV** Galileo message is broadcasted in **E1-B**



- **OS-NMA** is based on **TESLA** protocol (**T**ime **E**fficient **S**tream **L**oss-tolerant **A**uthentication).



Anti-Replay protection based on OSNMA unpredictable symbols!

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TIMING SERVICE ROBUSTNESS /// INTEGRITY

T-RAIM Time Solution Integrity Monitoring

For a typical Timing Receiver, the position is **known** and **static.**

Reduced number of unknowns has to be estimated with respect to the full Position Velocity Time (PVT) solution:

- Clock **bias**
- Clock **drift**

Redundancy can be exploited to:

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

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

- **T-RAIM** for **Single**-Constellation
- **T-RAIM** for **Multi**-Constellations

In case of Multi-Constellation T-RAIM, **Inter-System Offsets** (i.e. GGTO) and **Drifts** must be carefully handled.

OUTLINE

GIANO VALIDATION /// CALIBRATION ASPECTS

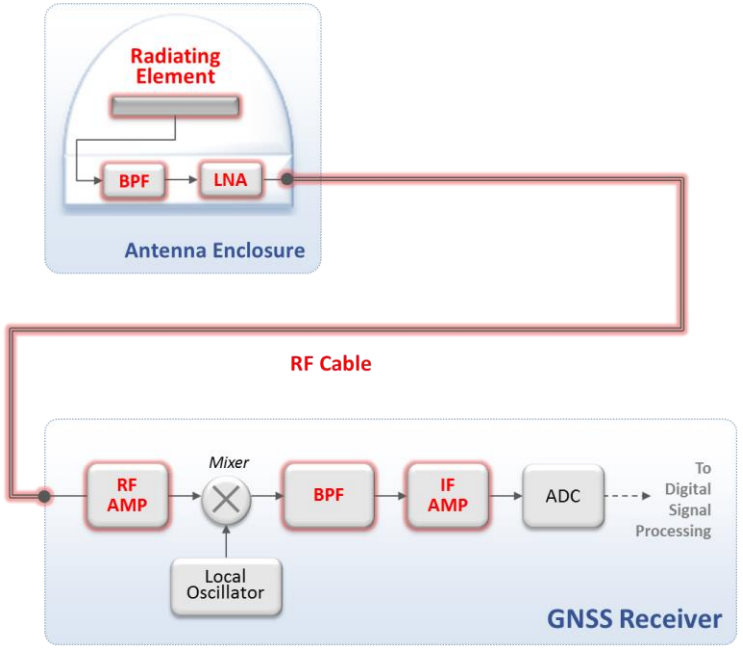
In-factory **calibrated equipment** is subject to **degradation** and needs to be **periodically re-calibrated**. Degradation is caused mainly by:

- **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**:

1. **Absolute Calibration**: delays are measured against a simulated test signal with identifiable RF timing marker:
   - **@ Antenna level** using a test inject probe antenna
   - **After Radiating Element** prior to filters and LNA
2. **Relative Calibration**: delays are measured against a reference receiver that has been previously calibrated.

A built-in **Auto-Calibration Technique** will be studied and its feasibility in a commercial product will be investigated for industrialization phase.



** Items in red introduce a substantial delay*

GIANO VALIDATION /// TEST STRATEGY

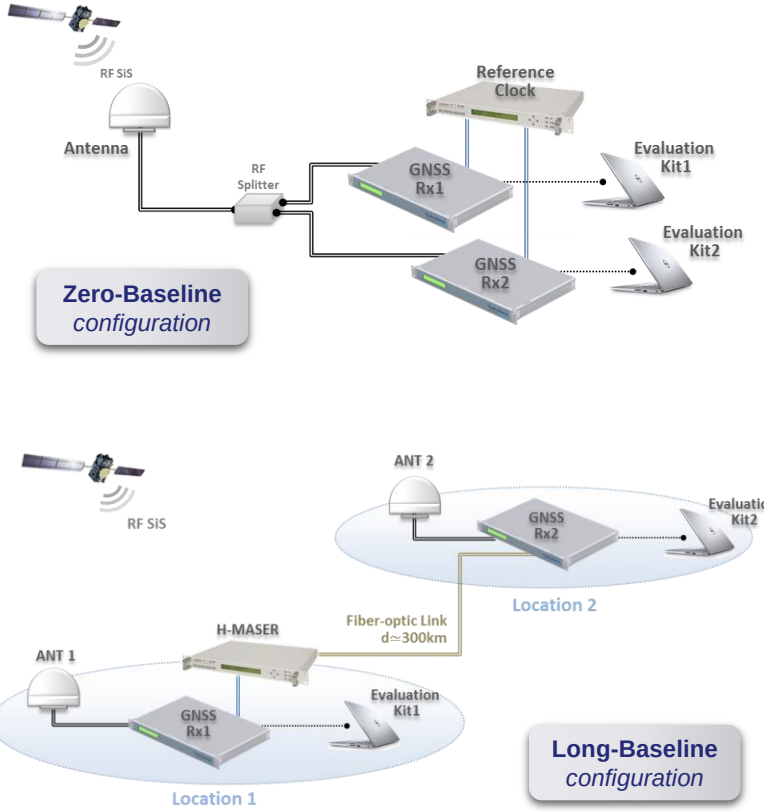
Timing platform will be tested through an **extensive validation test campaign**, conducted in **four phases**, through specific involvement of Team's experts and support of European laboratories:

1. **TAS-I** premises (Italy): verification of GIANO **interfaces**, **functionalities** and platform **integration**.

2. **SRC PAS** (Poland): **calibration** and **time transfer performance** verification in real environment ("Zero", "Short" or "Long" baseline tests).

3. **TAS-I** & **EC Joint Research Centre - JRC** (Italy): verification of platform **robustness** and ability to withstand **Jamming** or **Spoofing** threats.

4. **Italian National Metrology Institute - INRIM** (Italy): GIANO performance **benchmarking** against COTS multi-GNSS calibrated timing receivers and **UTC validation** at user level.



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GIANO VALIDATION /// STANDARDIZATION & CERTIFICATION

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

Existing standards are more related to **data format and 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 the power grid operators conforming to the old **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** (and possibly auto-calibration of the receiver during operation).
- **Remote monitoring** of overall performance may be required by specific applications.

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Thanks For Your Attention!

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