S4PRO

SMART AND SCALABLE SATELLITE HIGH SPEED PROCESSING CHAIN

Advanced Navigation and Communication solutions for Space Segment

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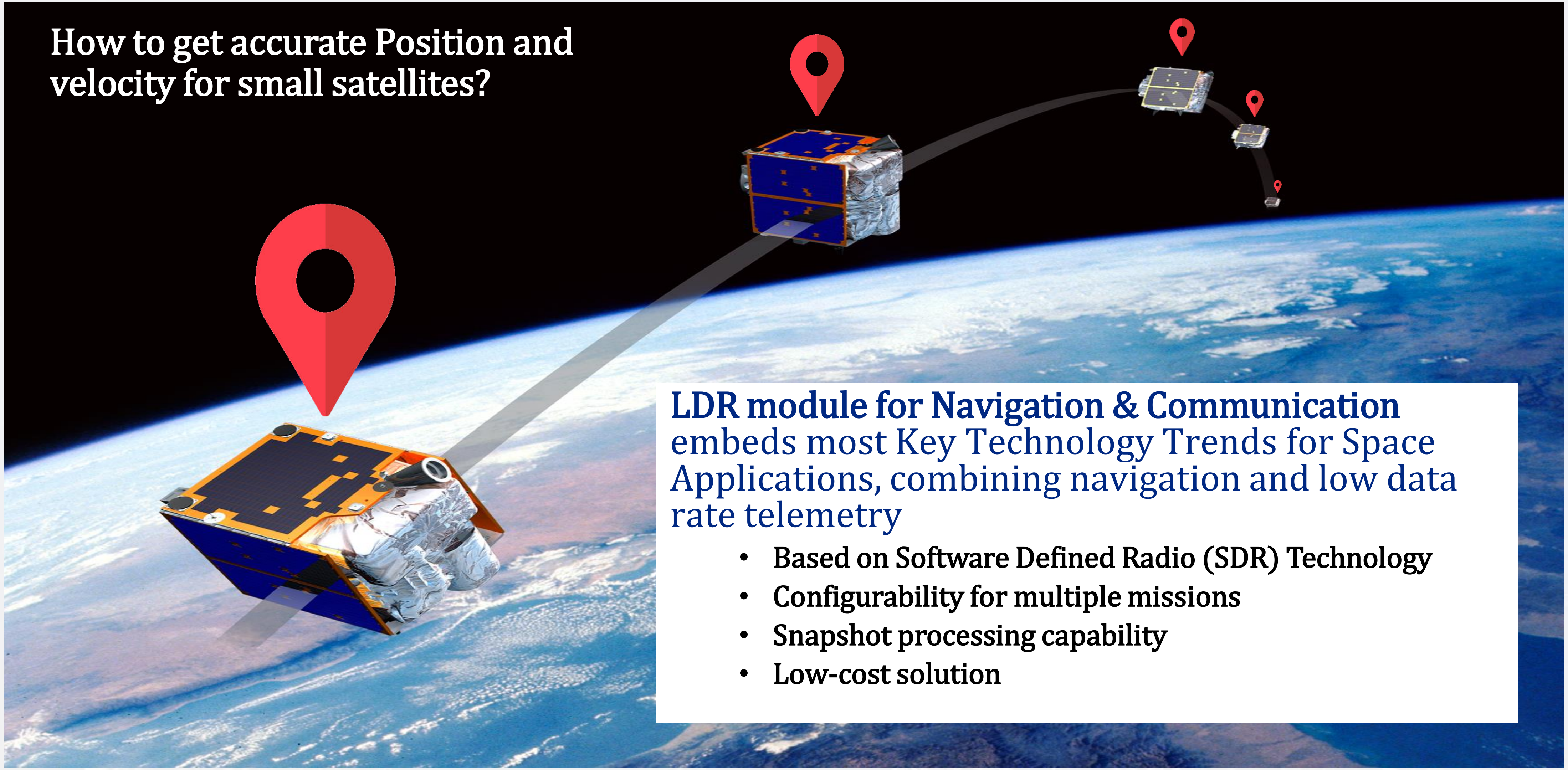
POSITIONING IN SPACE



How to get accurate Position and velocity for small satellites?

LDR module for Navigation & Communication embeds most Key Technology Trends for Space Applications, combining navigation and low data rate telemetry

- Based on Software Defined Radio (SDR) Technology
- Configurability for multiple missions
- Snapshot processing capability
- Low-cost solution

High level Requirements

Hardware and software development for space equipment has special requirements:

High reliability	Must address possible failures to anticipate automatic recover/restart strategies from a well known state
Design and Development strategies:	• **TDD** (Test Driven Development) • **HiL** (Hardware-in-the-loop) • **CI** (Continuous Integration)
Communication protocol	Communication with ground segment suitably designed for **low data rate link** in downlink and uplink (link is not always available).
Power budget	Must be managed efficiently to reduce power consumption
SDR (Software-defined radio) devices	The software can be upgraded and **updated remotely** to add new features, improving performance and security.

Positioning Algorithms

The SDR-based GNSS receiver developed in the scope of S4Pro project demonstrates:

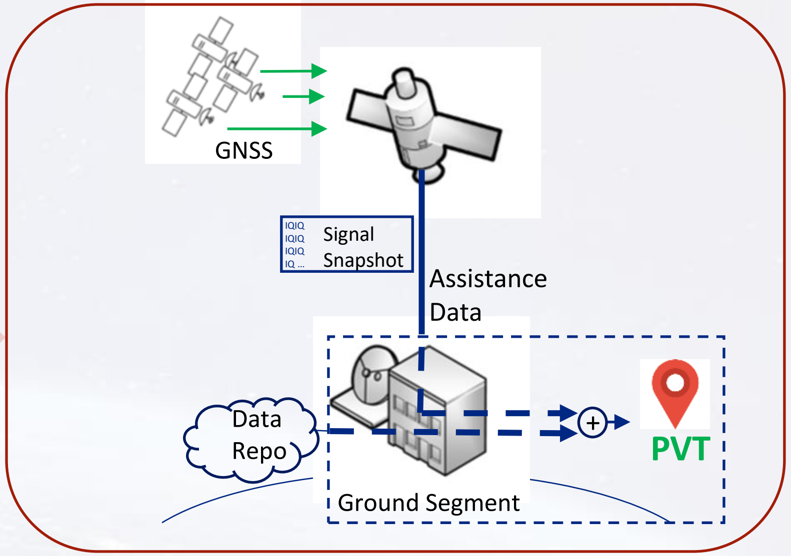
- Benefits of multi-constellation positioning (GPS + Galileo)
- Snapshot Processing method
  - **Innovative** concept for Space
  - All computations for snapshot positioning are done directly on-board (**SDR Module**)
  - **Low Power Consumption** w.r.t conventional positioning

Task	Conventional Positioning	Snapshot Positioning
Time to get position velocity and time (PVT)	Tens of seconds of signal tracking for receiver position ⇨	Receiver position determination using brief interval of received satellite signal ⇧
Power Consumption	May be always turned-on ⇨	Triggered for brief intervals when needed ⇧
Computational Burden	Computation forcibly on-board ⇨	Computation task easily performed directly in-space, or on ground server ⇧
Tracking of GNSS signal	Difficult to maintain signal tracking ⇨	No need of tracking ⇧

Snapshot Approaches

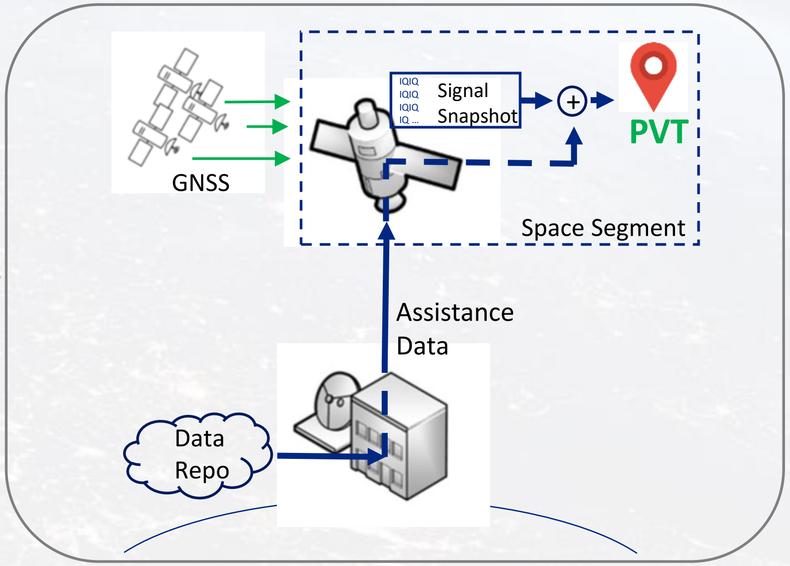
ON-GROUND Snapshot Processing

- PVT computation performed on ground station
- SDR capturing signal snapshot of GNSS SIS
- Send samples to ground segment
- High processing power on ground



IN-SPACE Snapshot Processing

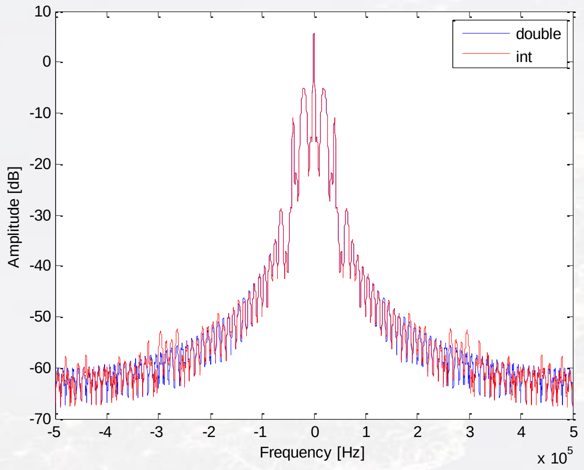
- PVT computation performed on-board
- SDR capturing signal snapshot of GNSS SIS
- Perform all signal processing and acquisition



Communication Module

Telemetry Application

- Merging incoming EO data with Navigation Results for GEO/Time tagging
- Apply data coding and modulation to get Telemetry (TM) RAW signal samples
- Telemetry signal format:
    - Interleaved IQ
    - 16-bit
- Store telemetry RAW data on local storage

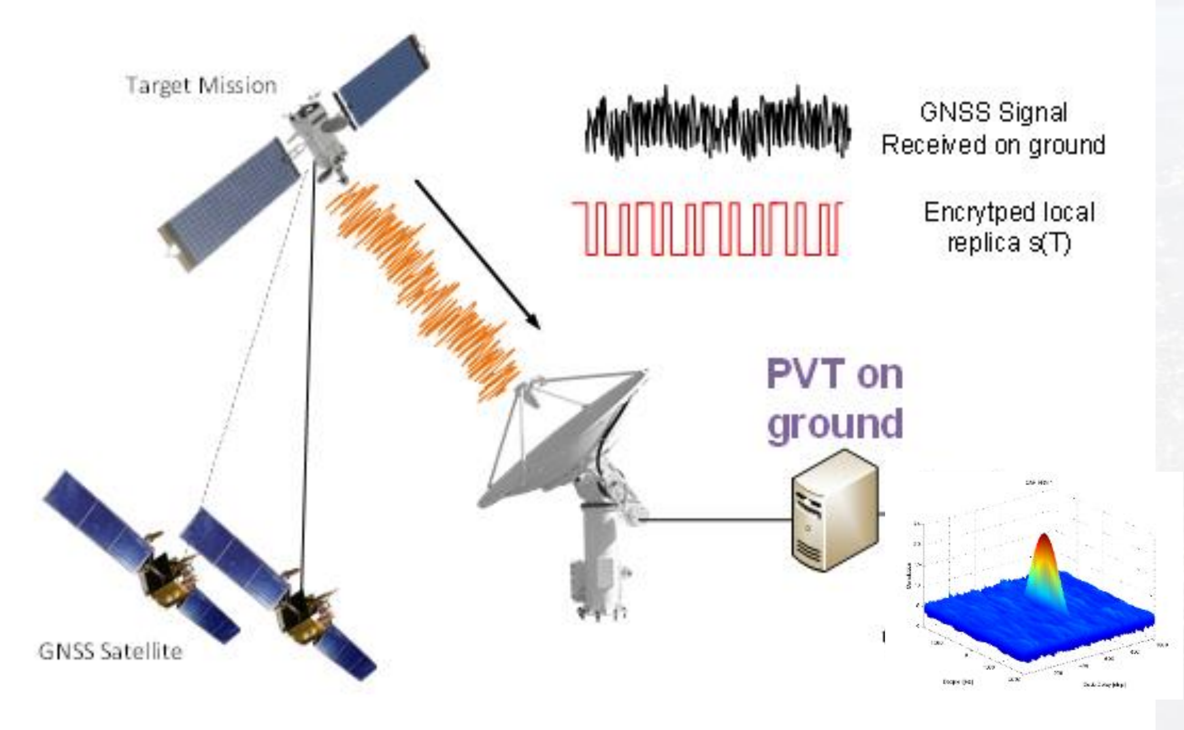


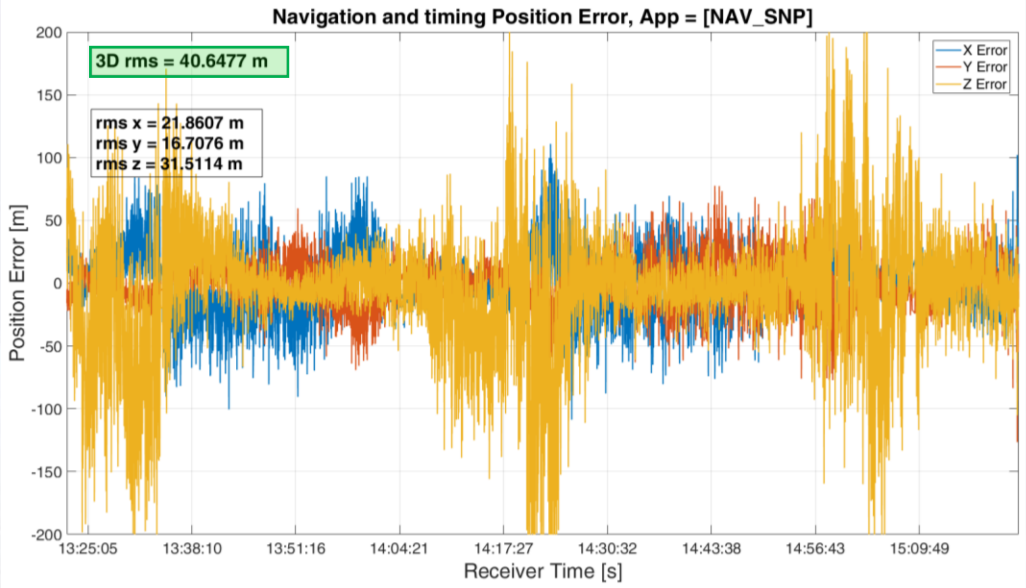
Welch plot for Telemetry sample signal

Ground Snapshot Results

Ground Snapshot Processing results

- Simulated LEO Trajectory (Using Spirent GSS6700 RFCS)
- Dedicated workstation with i7 CPU 16Gb RAM
- Dual GNSS (**GPS + Galileo**)
- Average time for snapshot PVT computation: **2.125s**
- Accuracy 3D RMS: **~40 m**





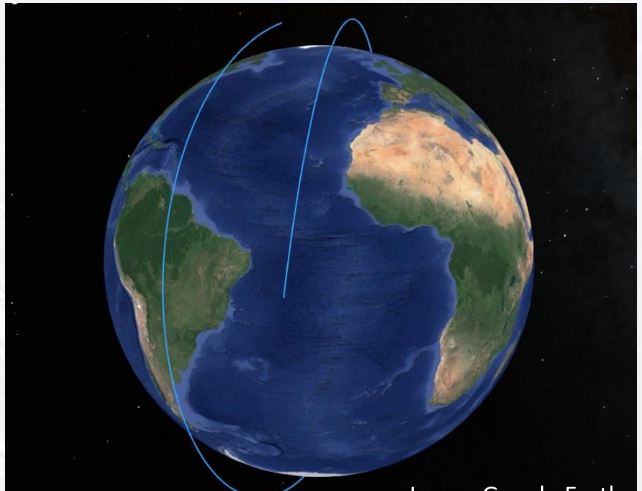
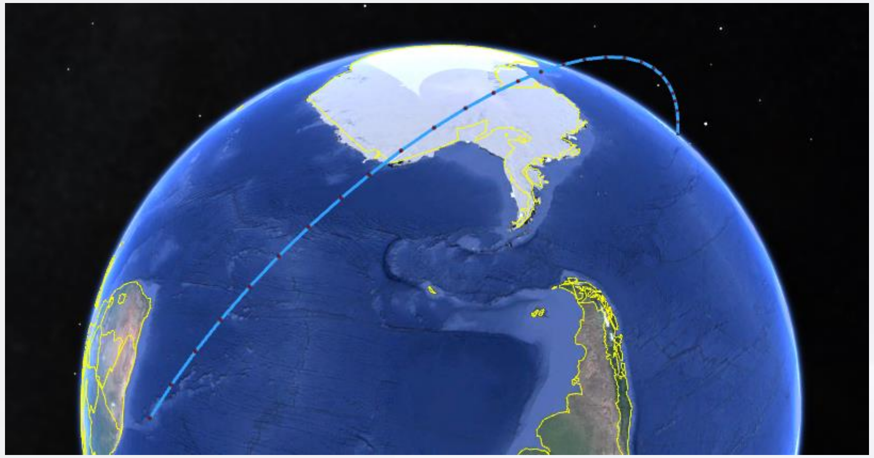


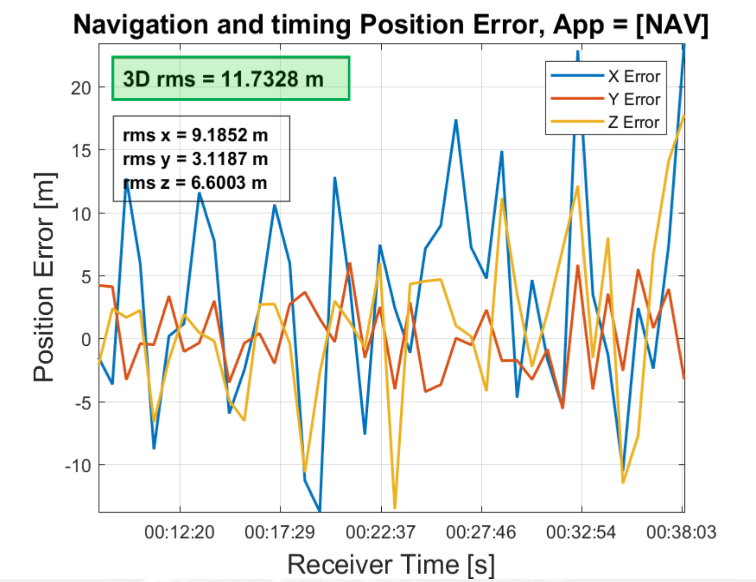
Image Google Earth Pro

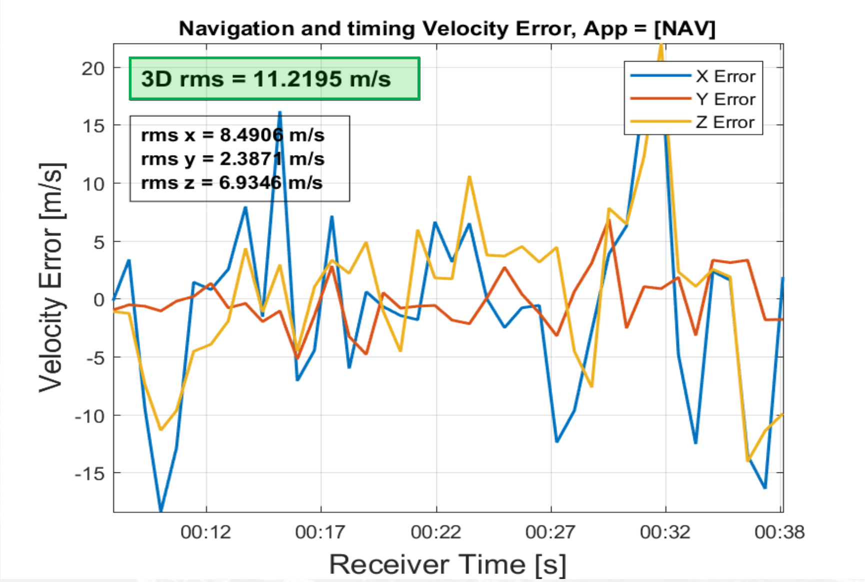
Space Snapshot Results



Space Snapshot Processing results

- Simulated LEO Trajectory (Using Spirent GSS6700 RFCS)
- Dual ARM® Cortex™-A9 processor and FPGA
- Average time for snapshot PVT computation: **16.3s**
- Accuracy 3D RMS: ~**12 m**
- Trade-off and optimizations can lead up to 10x time reduction

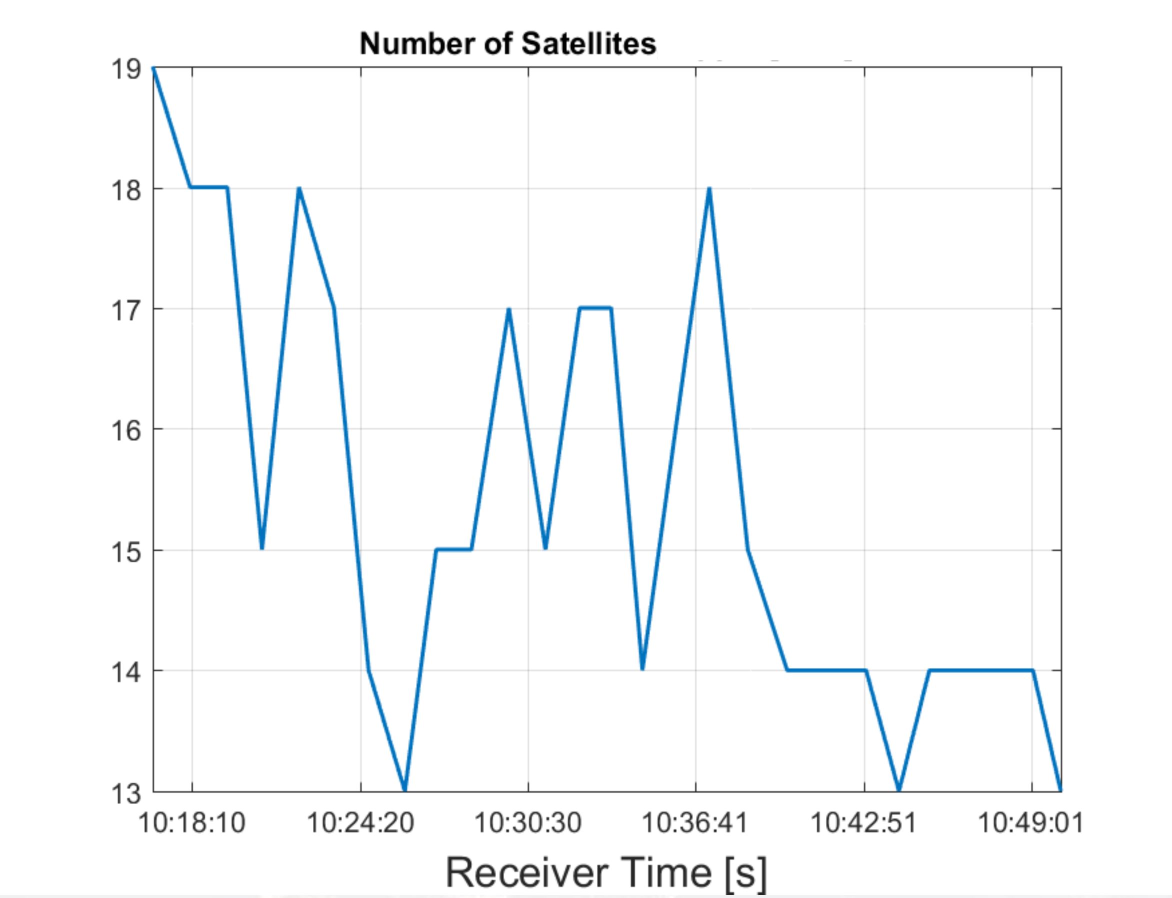


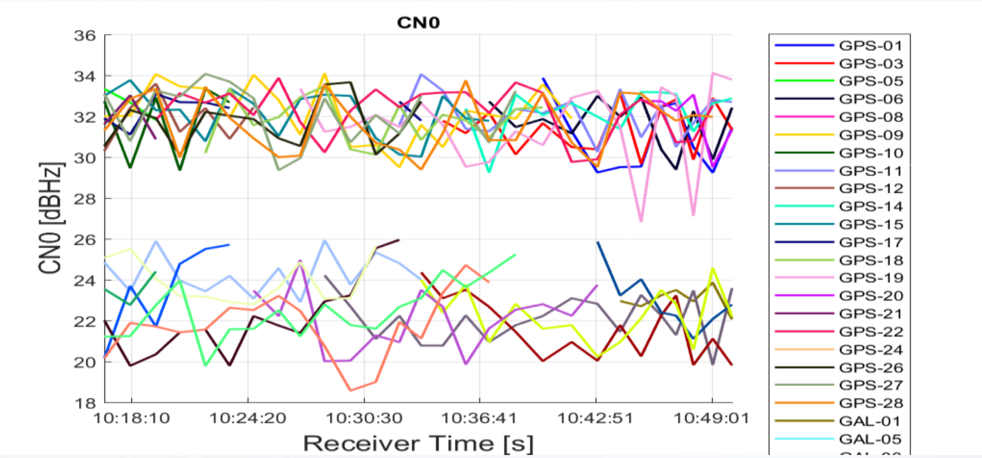


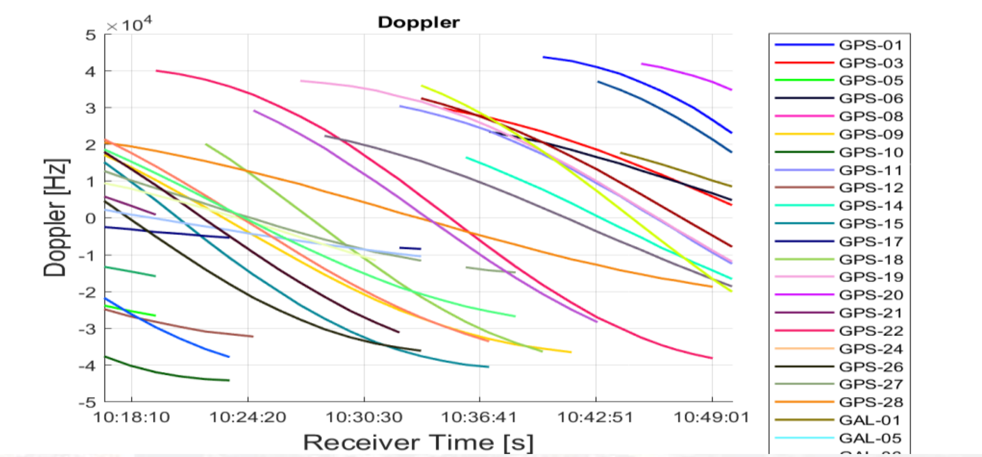
Space Snapshot Results

Number of satellites during the testing scenario

- C/N0 and doppler profile plots for each acquired GPS and Galileo signal



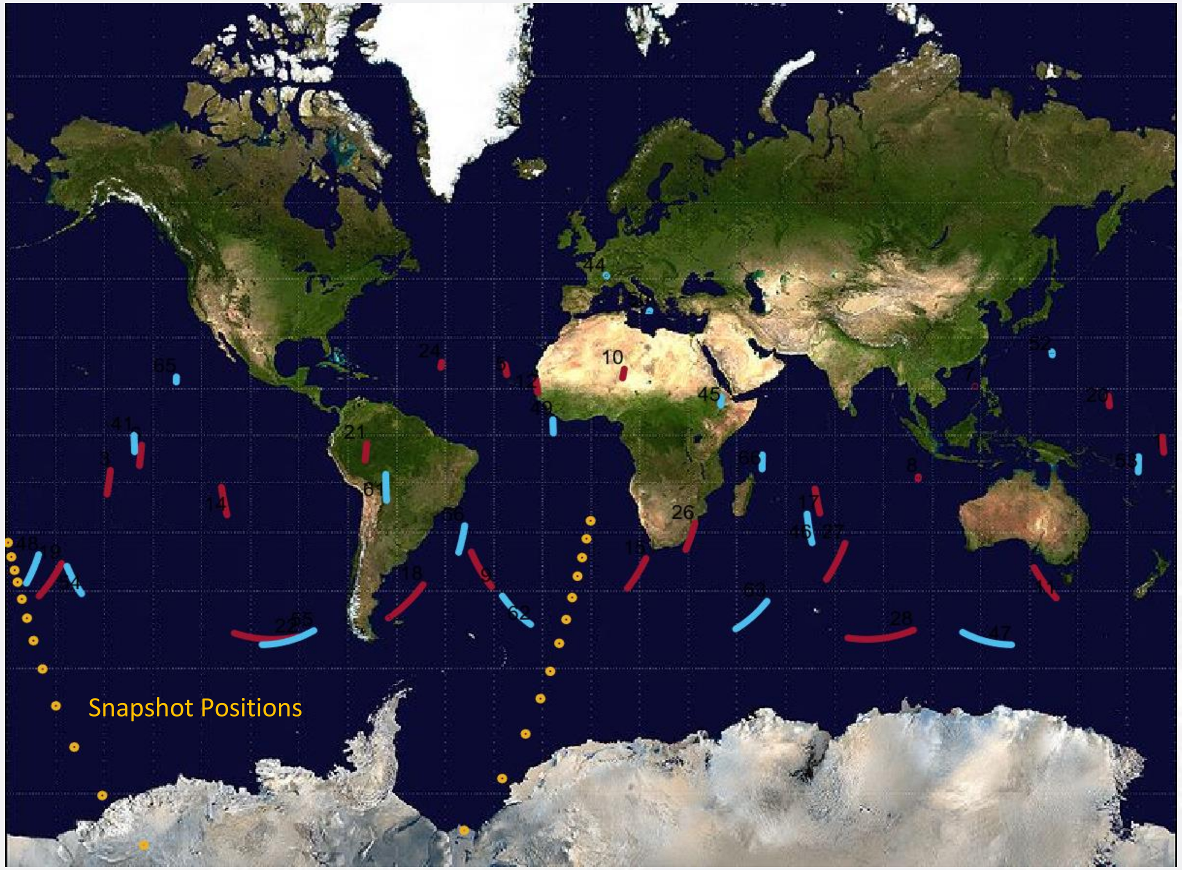


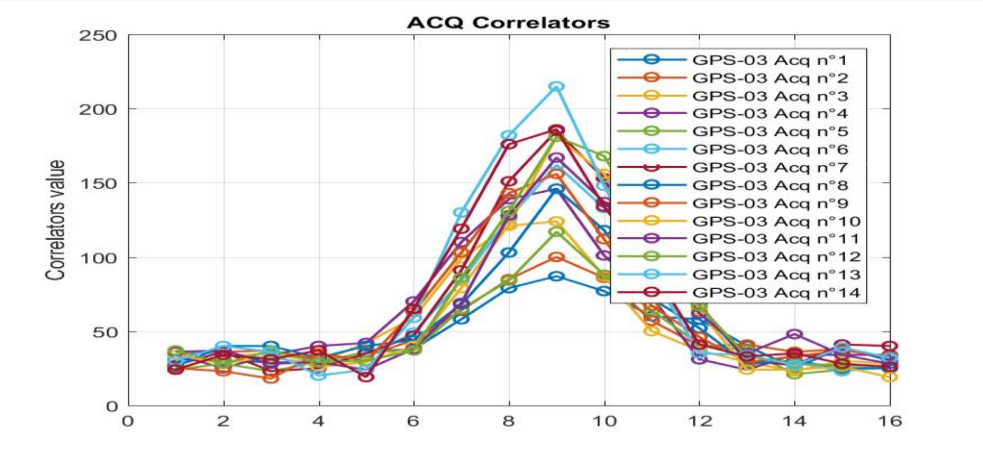


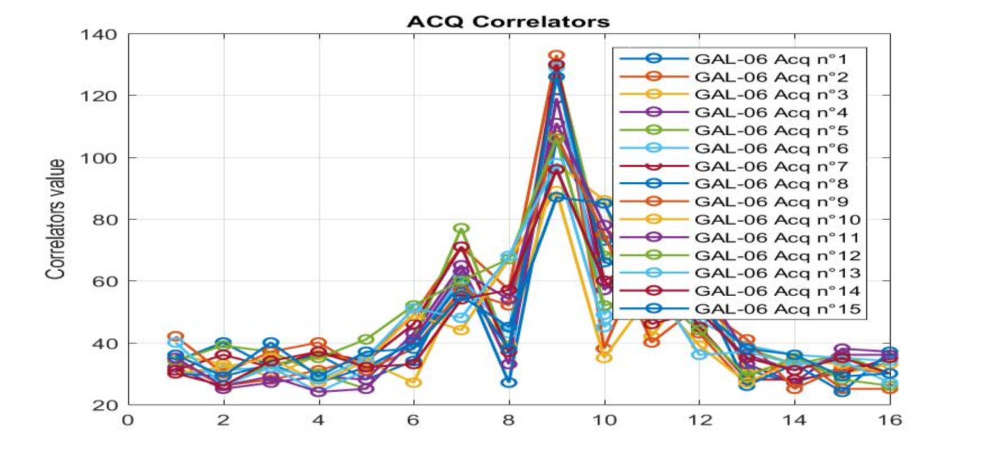
SPACE SNAPSHOT RESULTS

Ground track of reference LEO trajectory (snapshots)

- GPS and Galileo ground projections and their computed correlators







PROGRESS SUMMARY AND FUTURE MISSIONS

Low Data Rate Navigation & Communication module

- **SDR** technology to be used in space applications
- GNSS **snapshot positioning** investigation and performance evaluation
- PVT **accuracy** lower than 15 m
- Further optimizations in Doppler space analysis and acquisition strategies to improve performances
- Predisposition for:
  - Realtime signal tracking
  - Authentication
  - Interference mitigation

Qascom Module for Navigation and Communication in its enclosure

Detail on carrier board hosting the COTS SDR Module

THANK YOU

ANY QUESTIONS?

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