

## Context & Motivation

### Background

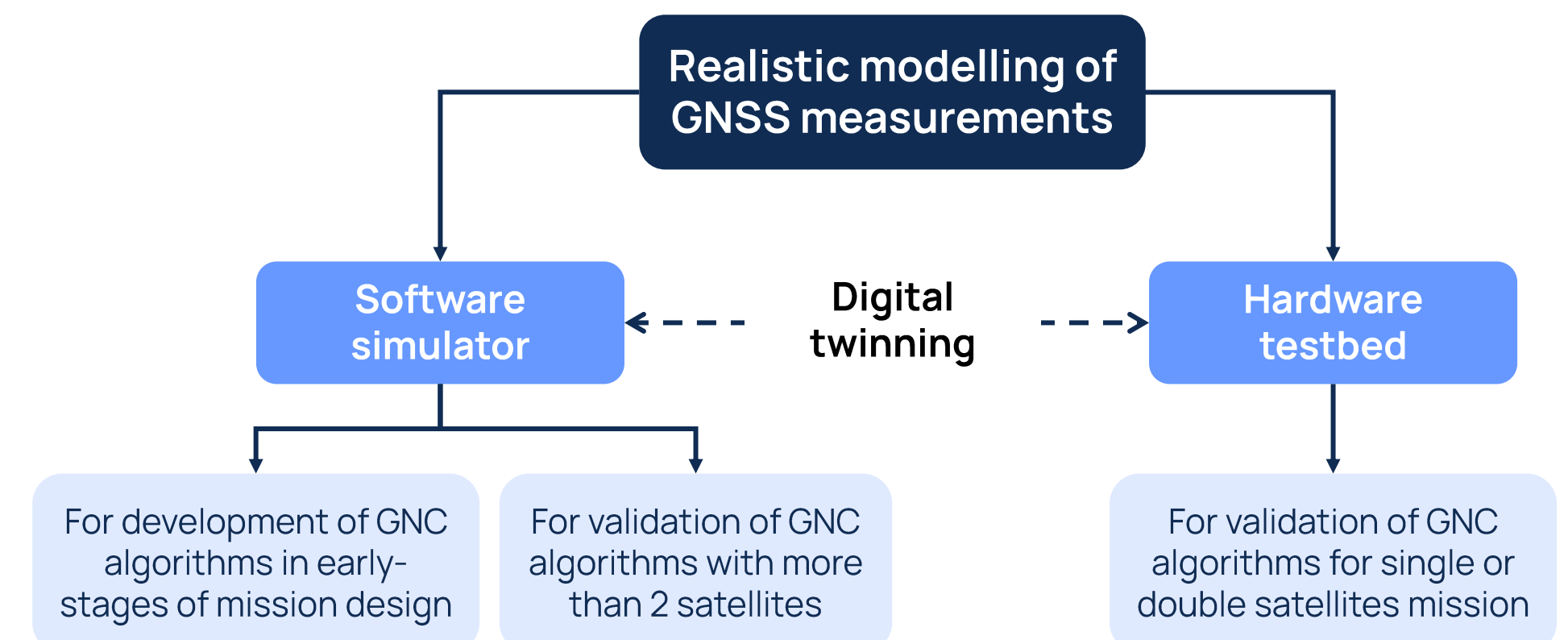
- **Distributed satellite architectures** represent a promising approach for future Earth Observation missions, offering improved measurement performance and relying on **GNSS for absolute and relative navigation**.
- Within this context, Politecnico di Milano is contributing to the **TriHex mission concept**<sup>1</sup> for passive radiometry, consisting of three satellites in a fixed triangular formation with approximately 8 m separation.

### Problem

- The challenging requirements (accuracy, robustness) for the relative navigation need a **realistic modelling of the GNSS measurements**.
- Such requisite is also needed at feasibility-level studies, where GNC analyses rely on flexible and PC-based modelling tools.

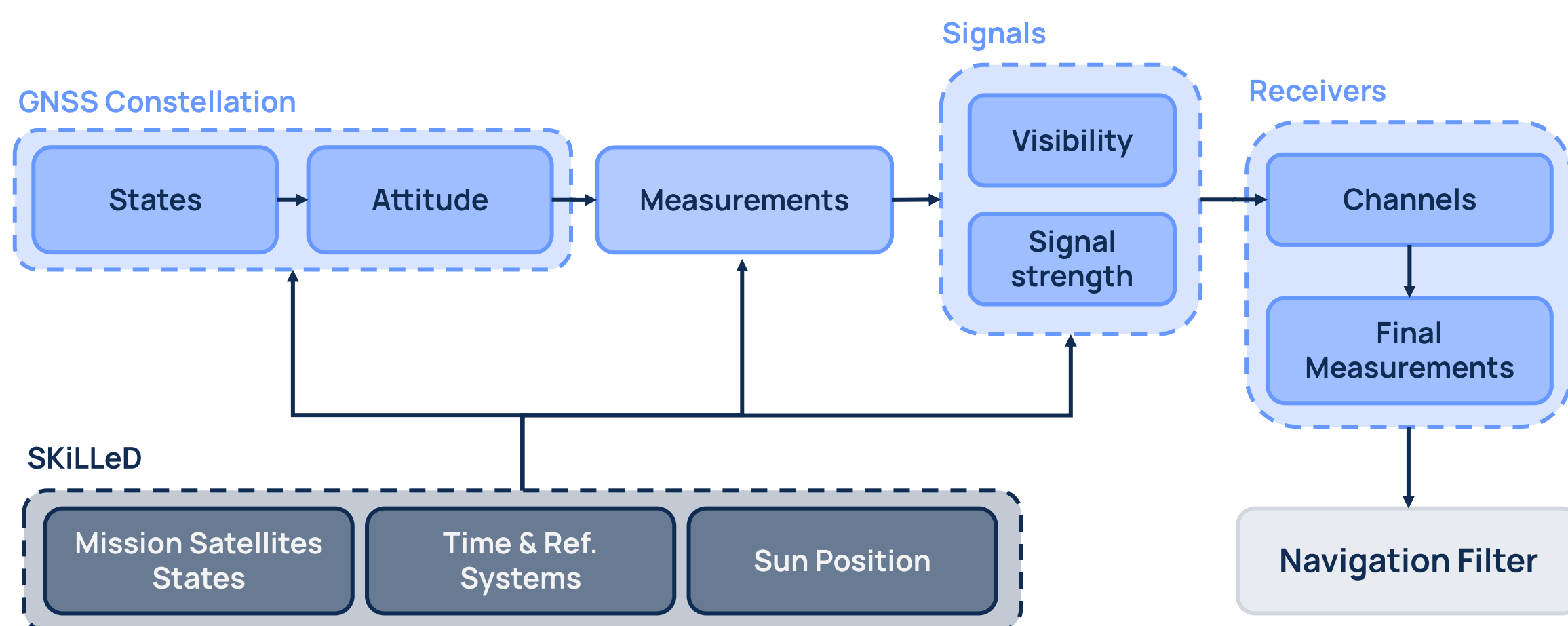
### Objective

- Model GNSS observables, by accurately replicating the **temporal and spatial variability** of the measurements.
- The simulation needs to be carried out within a **software tool**, to integrate seamlessly within the workflow of GNC algorithms development.



## GEMS (GNSS Environment and Measurement Simulator)

- Developed in **MATLAB/Simulink**
- The simulator structure is modular, consisting of masked blocks organised across several Simulink libraries.
- GEMS interfaces with SKILLed<sup>2,3</sup>, an already developed suite for satellite propagation.



### Errors modelled

- Receiver clock bias
- GNSS clock bias
- Ionospheric delay
- Integer ambiguities
- Broadcast ephemeris error
- Differential code biases
- Inter-system biases
- Relativistic effects
- Phase centre offsets
- Phase centre variations
- Wind-up effect
- Thermal noise

### IGS Products

- Precise Orbit Products
- Precise Clock Products
- GNSS Broadcast Ephemeris Files
- Ionosphere Products
- Differential Code Bias Products
- Antenna Files

### Constellations

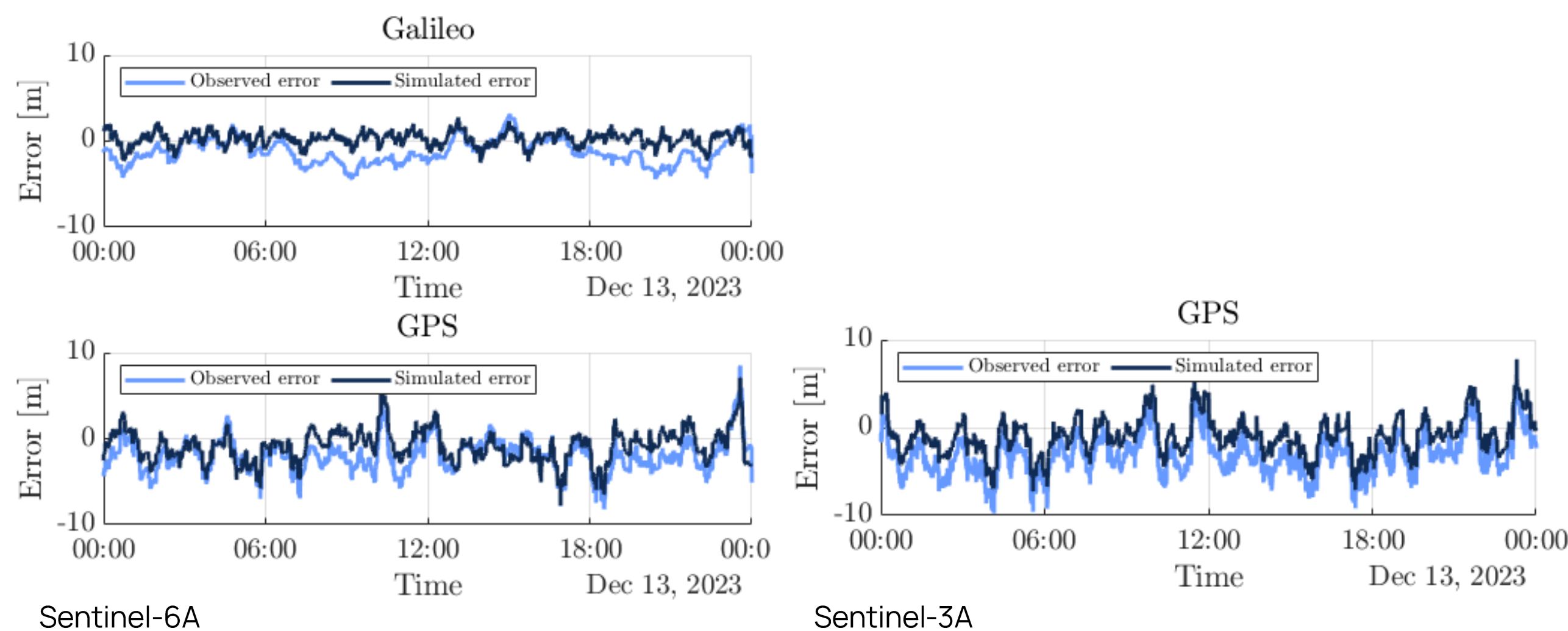
- GPS
- Galileo

## Validation & Results

### Validation with real flight data

Real flight data has been used as benchmark:

- Sentinel-6 (GPS + Galileo)
- Sentinel-3 (GPS)



Sentinel-6A

Sentinel-3A

### References:

- [1] Martín-Neira, M., Scala, F., Zurita, A. M., Suess, M., Píera, M., Duesmann, B. J., ... & Corbella, I. (2023). Trihex: Combining formation flying, general circular orbits, and alias-free imaging, for high-resolution L-band aperture synthesis. *IEEE Transactions on Geoscience and Remote Sensing*, 61, 1-17.
- [2] Gaias, G. et al. (2018-2023). Skilled (simulation kit for logic and layout design)- ff (formation flying). <https://www.compass.polimi.it/>. Accessed: 2025-07-14.
- [3] Gaias, G. et al. (2019-2021). Skilled (simulation kit for logic and layout design)- rdv (formation flying). <https://remove-project.polimi.it/>. Accessed: 2025-07-14.

### Validation with hardware testbed

Work in progress

GEMS will be put in parallel with the hardware testbed comprising:

- GNSS Radio-Frequency simulator (Spirent GSS7000)
- Receiver (NovAtel OEM729)

