



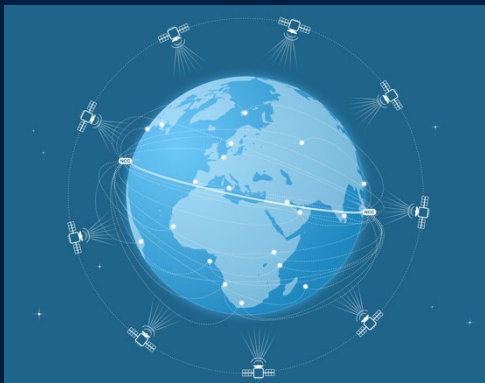
# Advanced GNSS Correction Techniques Adapted for Reliable Precise Time Dissemination

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WSTS | Vancouver

16 March 2023

# Today's Agenda



## 1. Technical Background



## 2. Results



## 3. Performance and hardware

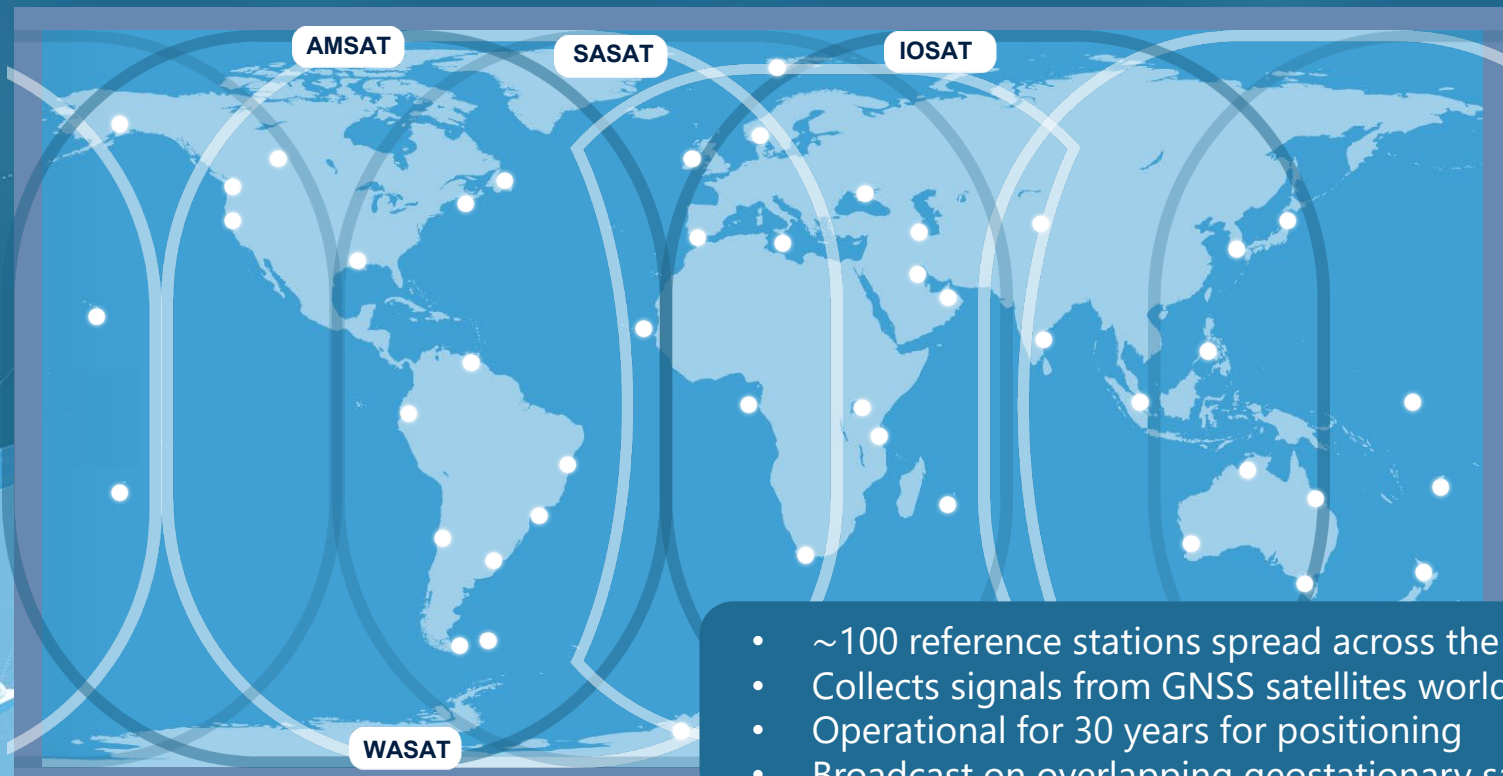
# 1. Technical Background

# Precise Point Positioning (PPP)

- Real-time precise orbits and clocks
- Advanced error modelling
- Multi-frequency GNSS signals
- Four GNSS constellations:
  - GPS
  - Galileo
  - BeiDou
  - GLONASS
- > 10 x accuracy improvement
- Highly reliable time and position



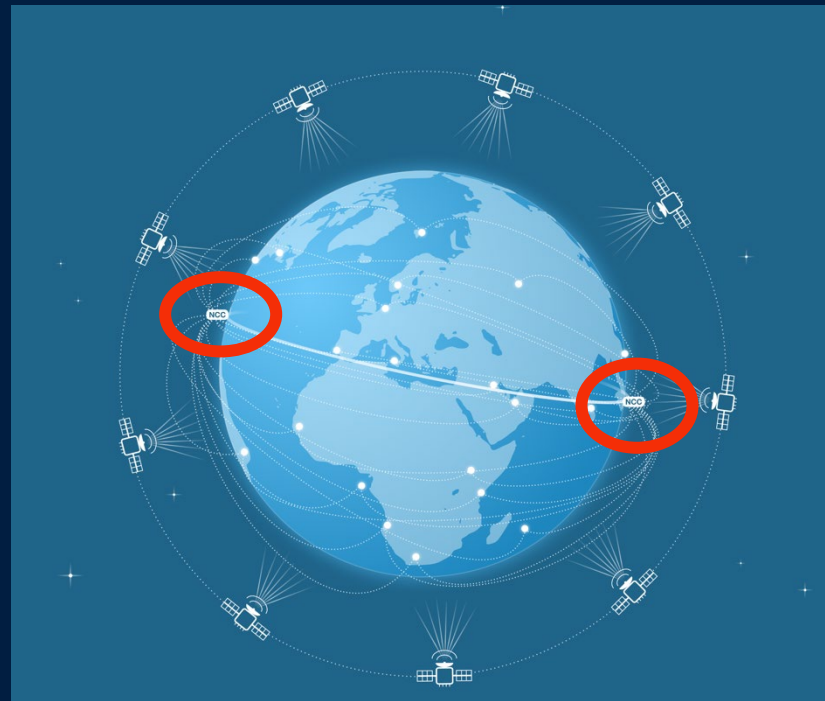
# GNSS stations and broadcast beams from GEO satellites



# Control Centers

## Two Network Control Centres:

- Geographically separated
- Running **fully independent S/W**
- Very high **99.999% uptime**



# Navigation Message Authentication

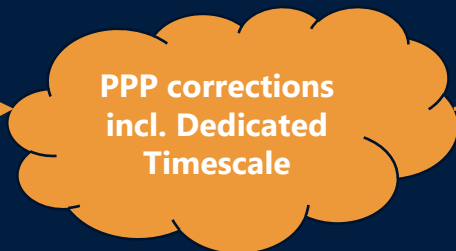
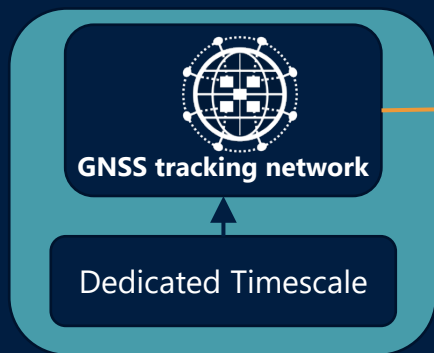
- **NMA – Navigation Message Authentication**
- **BMA – Broadcast Message Authentication**
- Receiver compares received **authentic hash** to **hash from local GNSS** observations
- Hashes match? **NMA authentication!**

**Spoofers**

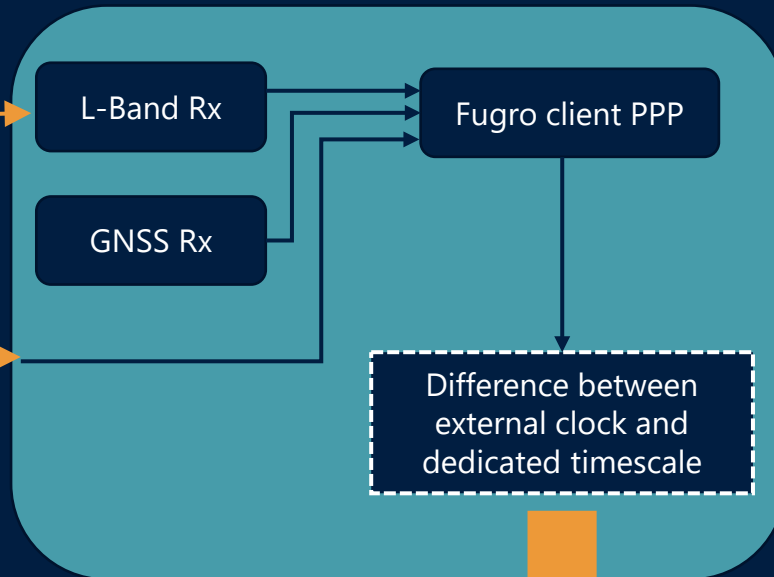
**Trusted GNSS**

# Data flow

## Fugro Infrastructure and processing



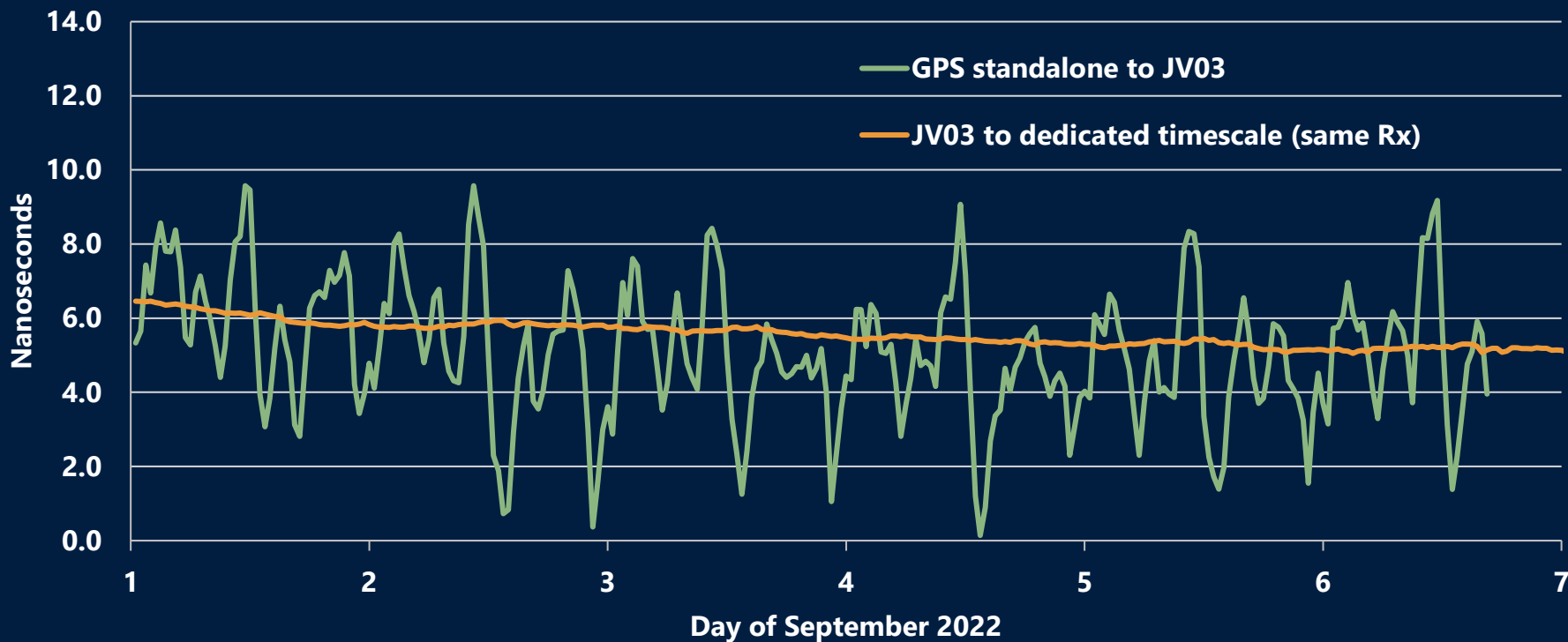
## GNSS Receiver Chip



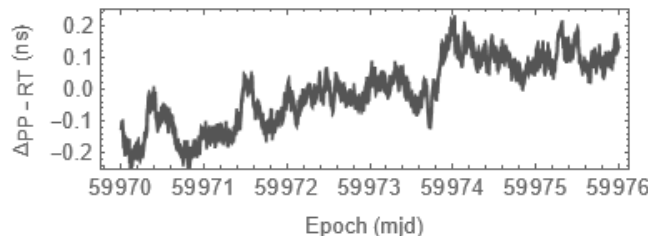
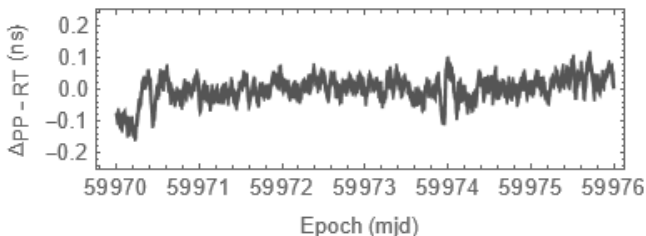
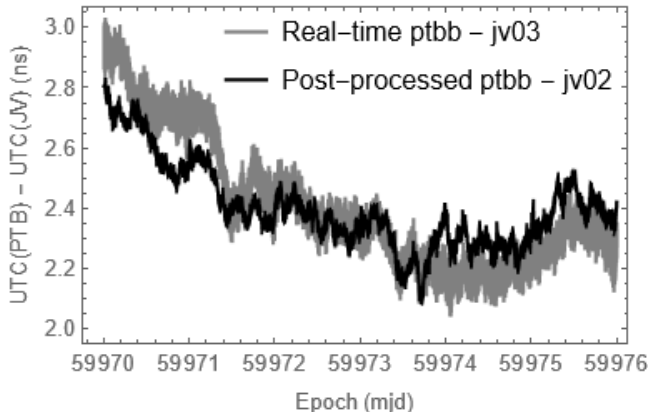
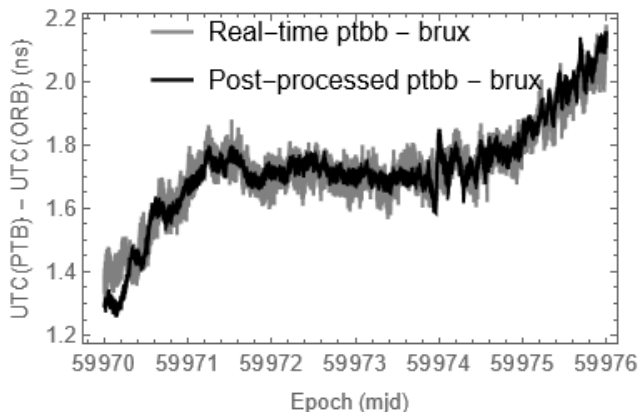


## 2. Results

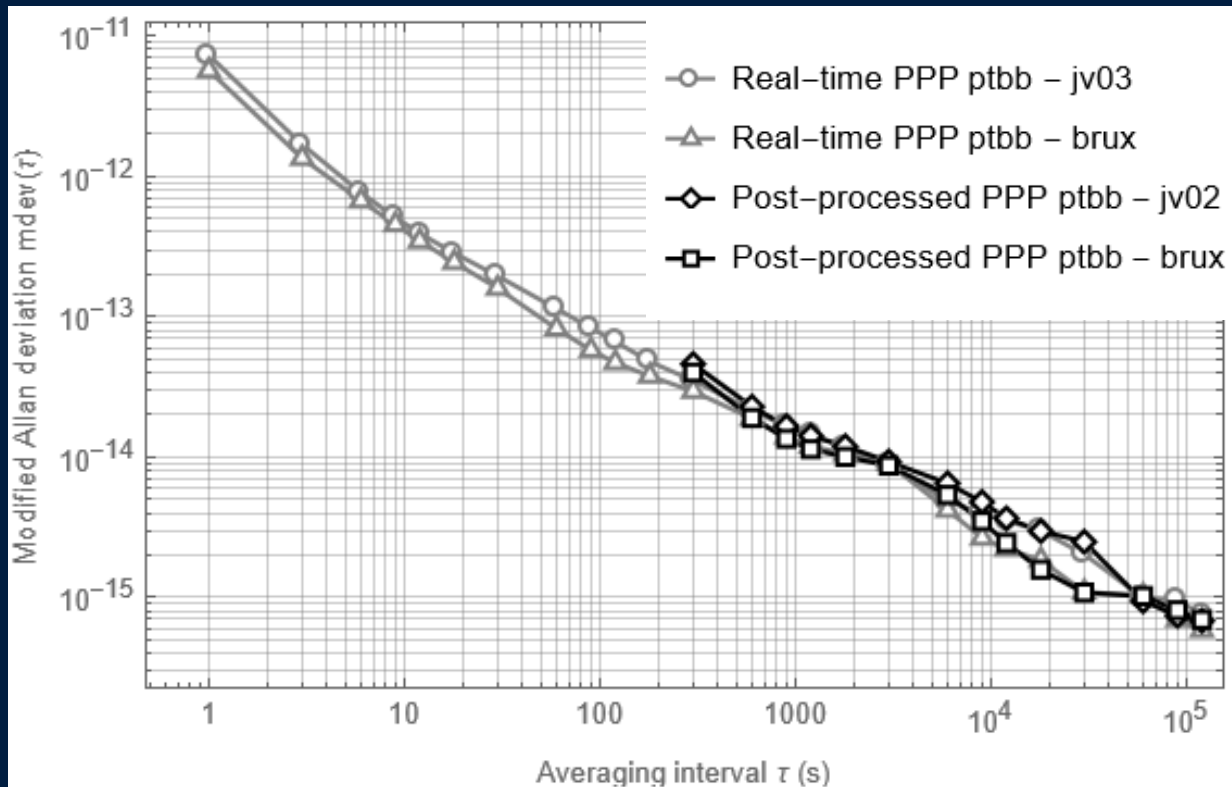
# Real-time comparison to GPS at the Norwegian NMI



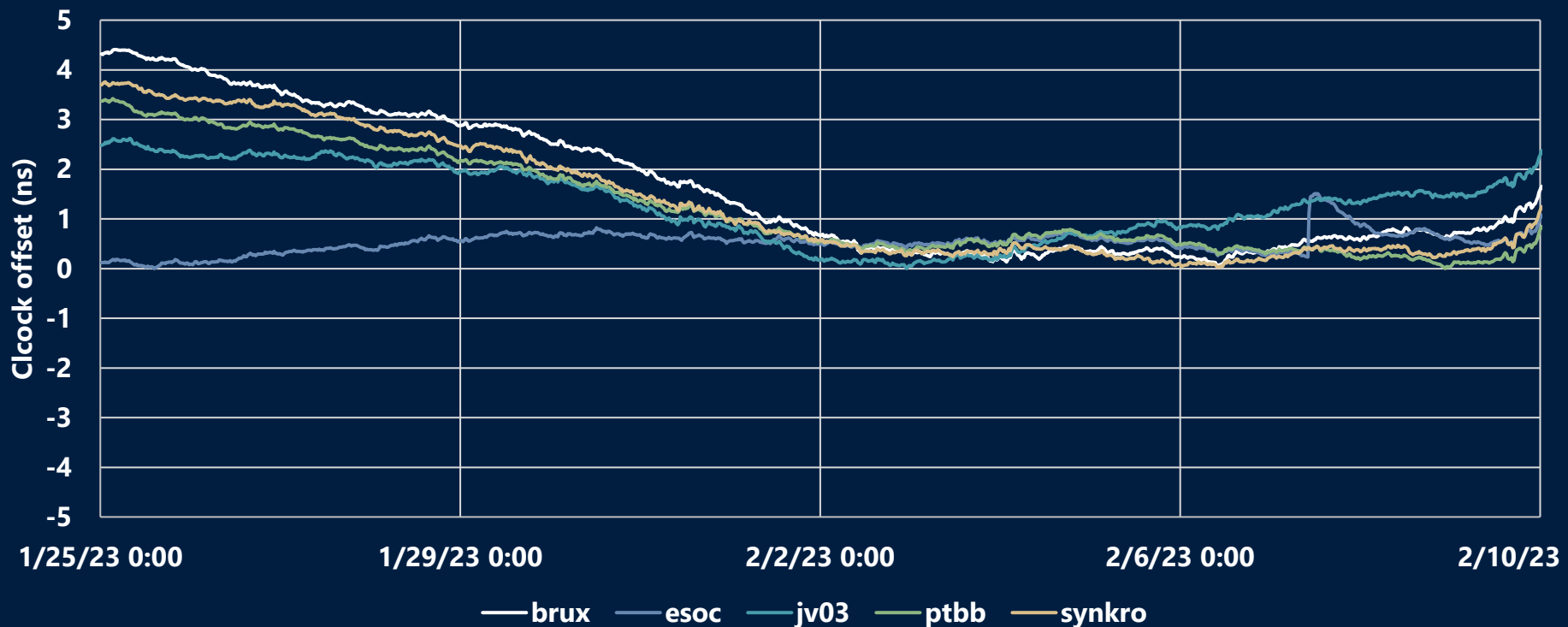
# Real-time versus official post-processing by Norwegian NMI



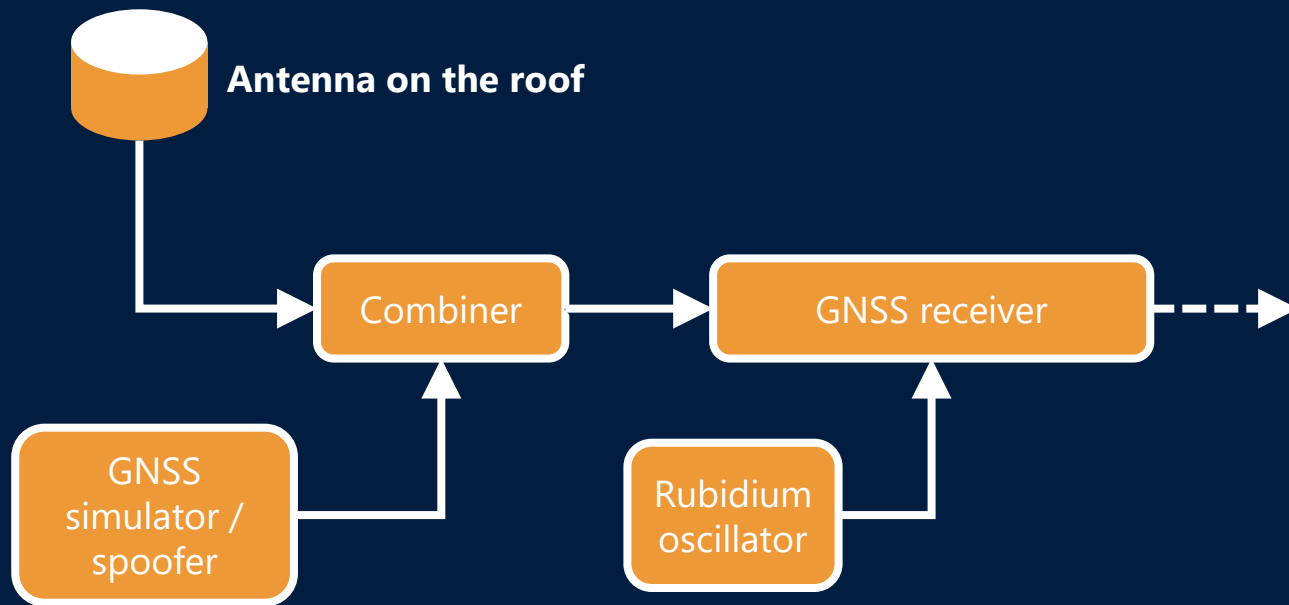
# Real-time versus official post-processing by Norwegian NMI



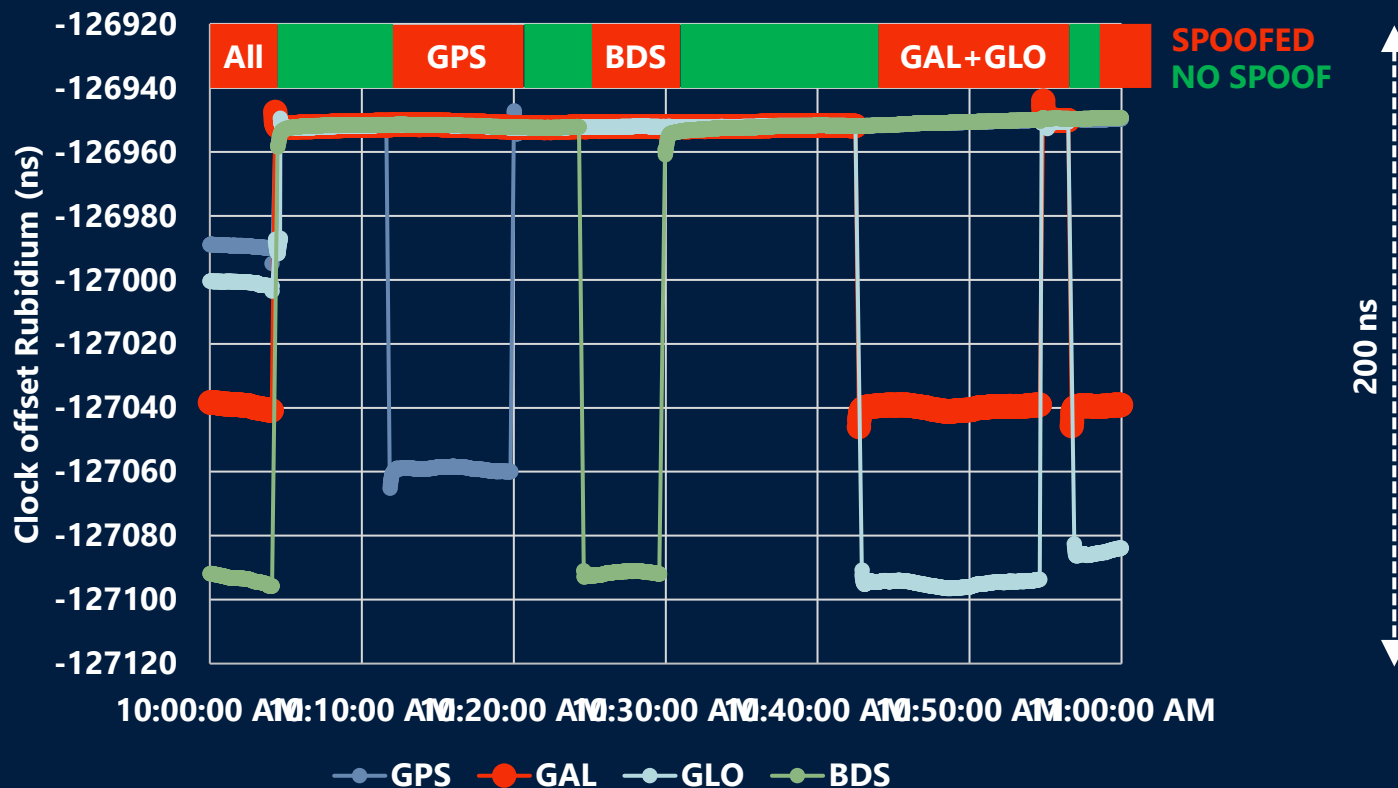
# Real-time comparison 5 masers over 16 days



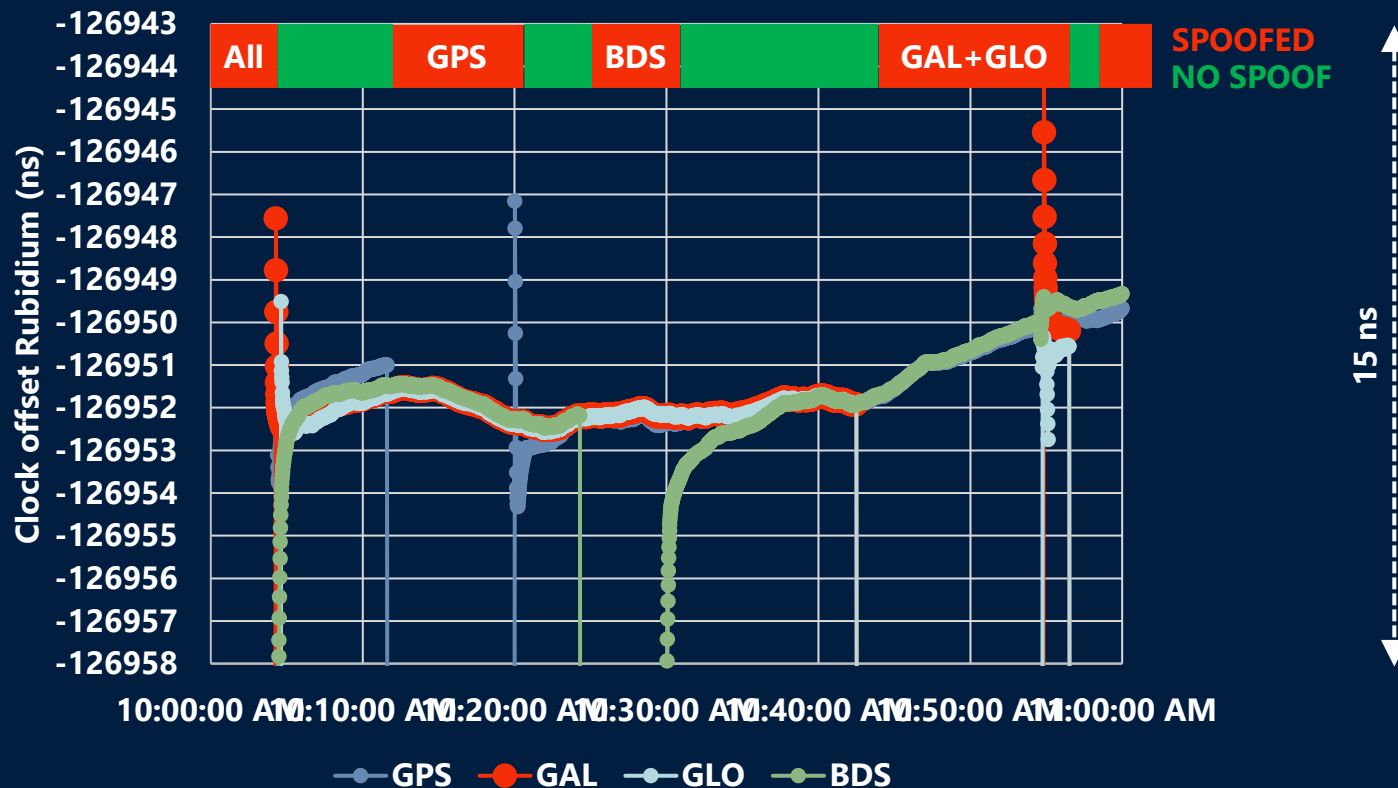
# Spoofing campaign at Fraunhofer IIS, Nuremberg



# Efficient spoofing detection in time domain

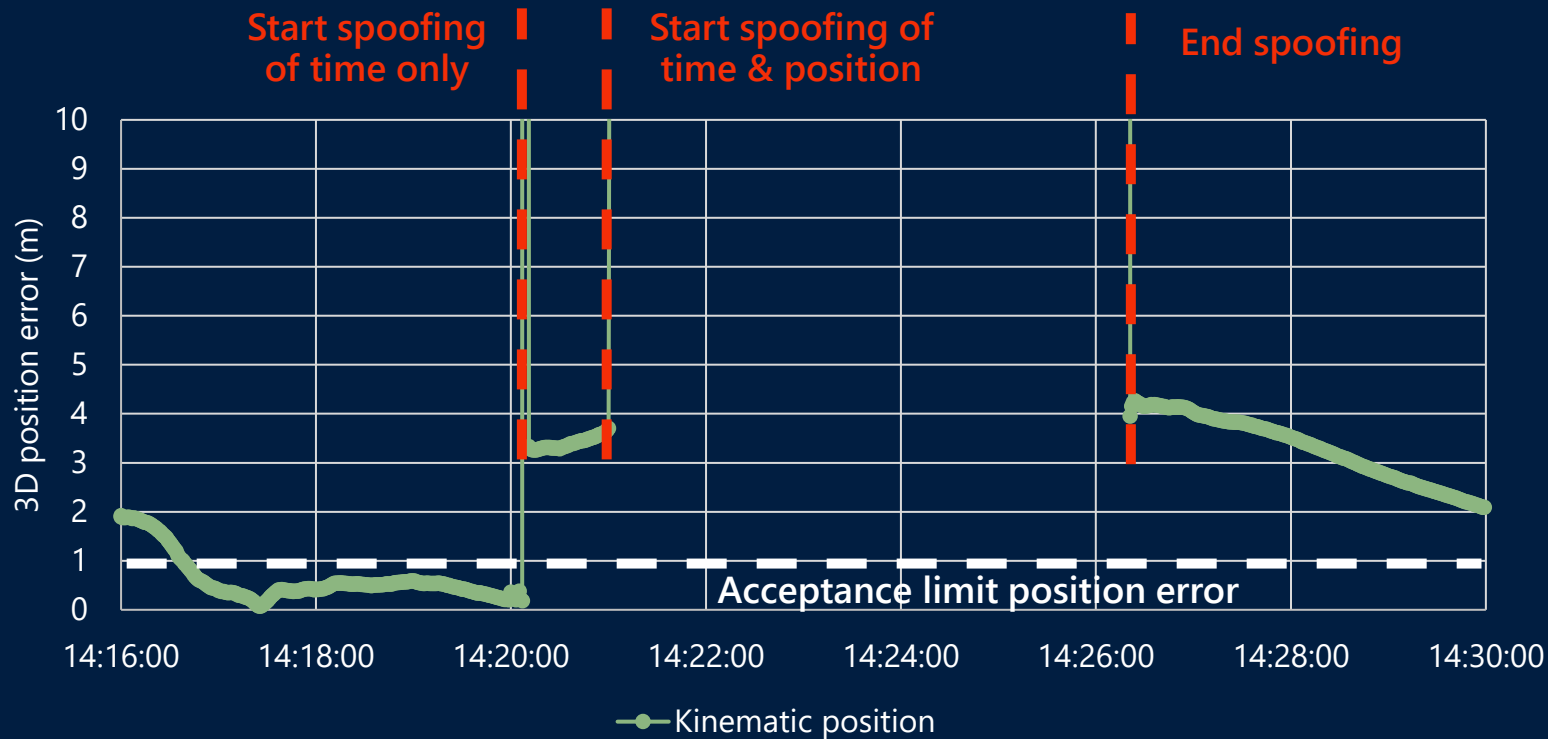


# Spoofing detection - zoomed in on Y-axis





# Kinematic PPP position error is also an efficient spoofing detector for a static installation



# 3. Performance and hardware

# Performance

- <5ns **accuracy to UTC** – 95% of the time
- <1ns **accuracy to dedicated timescale**
- >10x better than existing high-end GNSS receivers

High Accuracy

- Navigation Message Authentication (NMA)
- **Traceability** of timescale to UTC

Resilience

# Examples of interoperability / compatibility

- **Time transfer between collaborating NMIs** using existing GNSS hardware on site for **real-time UTC(K)** monitoring
- Inside **Septentrio mosaic-T GNSS chip**:
  - Multi-constellation + Multi-band GNSS module
  - Inmarsat L-Band correction receiver
  - Protection against spoofing and jamming
- Inside Clock Module for **Meinberg Timing System**:
  - Verifies status of NMA and takes correction data into account to improve timing resilience



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Any questions?



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