Galileo High Accuracy Service Performance Assessment

J. Nosek, J. Douša, P. Václavovic

Geodetic Observatory Pecný (GOP), Research Institute of Geodesy, Cartography and Topography (RIGTC), Czech Republic

e-mail: jakub.nosek@pecny.cz

Co-funded by the European Union

ABSTRACT

The Galileo High Accuracy Service (HAS) is a new Galileo service providing free of charge high accuracy Precise Point Positioning (PPP) corrections in real-time. The HAS corrections for Galileo and GPS constellations are provided through the Galileo E6-B signal component and also by terrestrial means (Internet). The HAS corrections currently support Galileo E1, E5a, E5b, E6 and GPS L1, L2C frequencies and consist of orbits, clocks and code biases. In the future, HAS will also include phase biases and atmospheric corrections. A target accuracy for horizontal and vertical positioning of Galileo+GPS solution is 15 cm and 20 cm, respectively. The poster focuses on monitoring the performance of the HAS which includes assessments of orbital errors, clock errors and positioning errors. A comparison of the HAS orbits and satellite correction clocks with the final product from the Center for Orbit Determination in Europe (CODE) showed a high accuracy of the corrections and its compliance with the declared accuracy. The HAS performance was analysed in terms of the Galileo+GPS PPP performed at global reference stations using the G-Nut/Geb software with focus on horizontal and vertical position accuracy and convergence time. Results showed that the HAS accuracy targets for the currently operational phase (phase 1) as published by the Service Definition Document (SDD) are achievable. However, the results also show that the convergence times achieved with the current HAS phase 1 are still longer than the convergence time targets that are defined in the SDD for the HAS phase 2.

GALILEO HAS PERFORMANCE MONITORING SYSTEM AT GOP

The Galileo HAS performance monitoring at GOP is implemented in a multi-step approach (Figure 1). The input products are GNSS observation files from the selected global reference stations (Figure 4), consolidated navigation data files, precise correction files (Galileo HAS SIS and IDD products), final orbit and clock product files and additional precise models.

An assessment of Galileo HAS orbit and clock corrections is performed on a daily basis using the G-Nut/Aset software. Differences of HAS orbit and clock corrections with respect to the reference product are estimated for every 5 minutes. The orbits are compared in terms of 3D position, radial, along-track, and cross-track components for individual satellites. The satellite clock offsets are then compared by differencing between satellites to eliminate a difference in product reference datum (a common offset).

The Galileo HAS horizontal and vertical positioning assessment is performed with the G-Nut/Geb and the G-Nut/Apep software. The former is used for estimating daily station positions using the Precise Point Positioning (PPP) method (Table 1) and the latter for post-processing daily PPP results into consistent station time series and for providing monthly statistics. The assessment of the site measured positioning of the HAS service is performed by applying a forward filter when using Galileo and GPS 30s observations from daily RINEX files. The mean horizontal (HPE) and vertical (VPE) positioning errors are calculated from estimated positions (after removing the convergence period) from the North, East and Up residuals with respect to reference (monthly mean) coordinates.

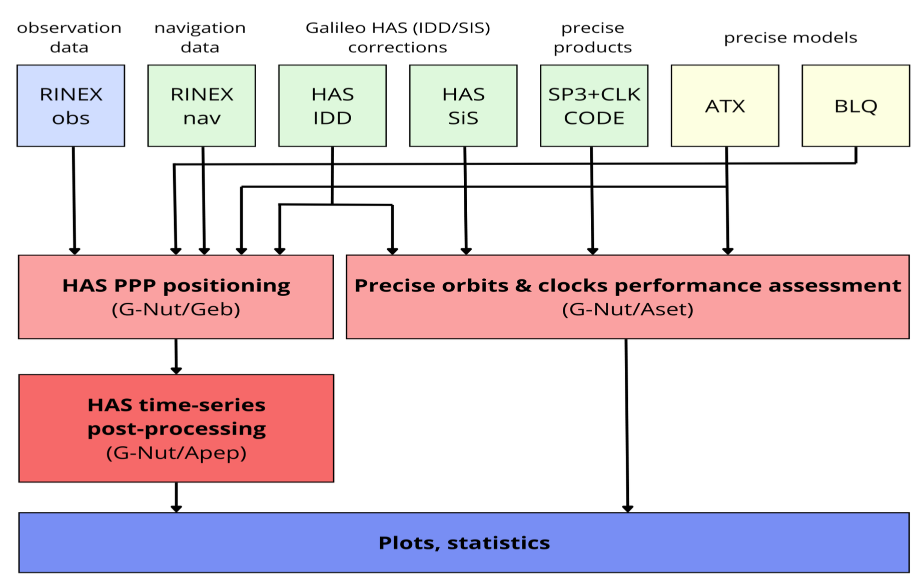

Figure 1: HAS performance monitoring system developed at GOP.

Processing strategy	Description
Navigation data	Galileo/GPS INAV/LNAV (GOP's BRDC files).
Precise corrections	HAS orbit and clock corrections of active satellites.
Observations	code and phase observations (E1+E5b, L1+L2).
Observation weighing	1/sin(elevation)^{2}, phase = 100 * code.
Elevation angle cut-off	7 degrees.
Phase ambiguities	estimated as float values.
Coordinates	estimated as kinematic positions.
Receiver clocks	estimated continuously using a white noise.
Satellite clocks	introduced from precise corrections.
Ionosphere	slant ionosphere delays estimated using dual-frequency observations.
Troposphere	Saastamoinen + GPT; random walk mm/sqrt(hour)
Antenna models	igs20.atx
Solid earth tides	IERS 2010 model
Ocean tide loading	IERS2010 + FES 2004 tidal model

Table 1: PPP strategy for estimating positioning errors.

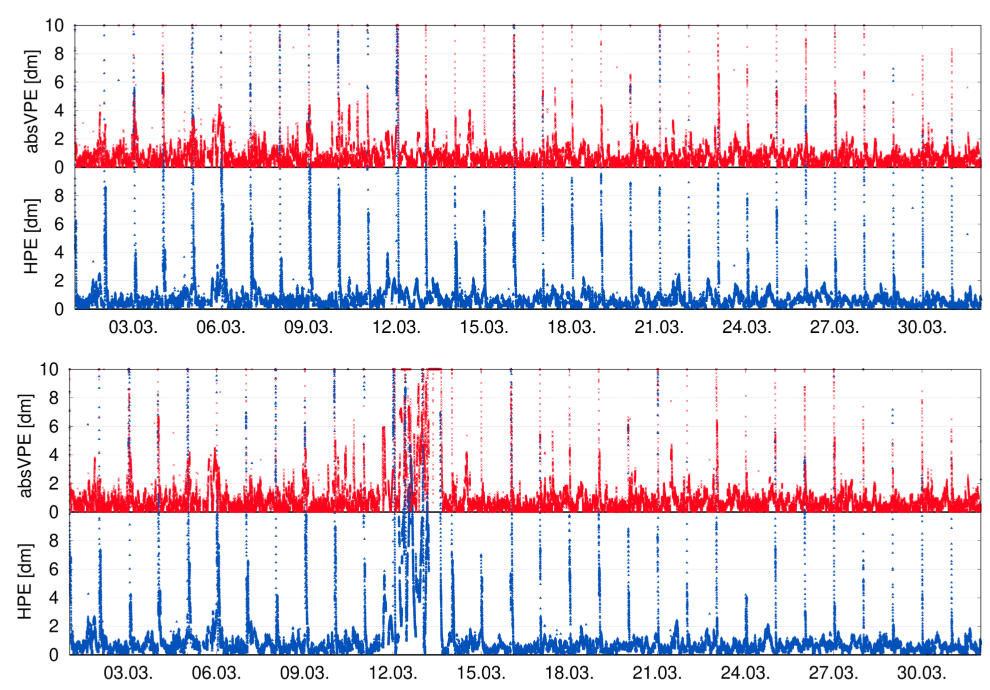

Figure 3: Example of HPE/VPE time series (incl. convergences) at BRUX00BEL station for HAS IDD (top) and HAS SIS (bottom). A degradation occurred for the SIS data source during March 12-13, 2024. It is related to a lower quality of Galileo satellite clocks obtained from a single GNSS receiver (without guarantee of error-free data collection).

Figure 2: Mean 68% and 95% percentile HAS IDD/SIS HPE (top) and VPE (bottom) over 15 global stations. Increased 95% percentiles (HAS SIS statistics) reflect the PPP degradation for a majority of stations during March 11-13, 2024, which has been still the only major difference observed between the two Galileo HAS data sources.

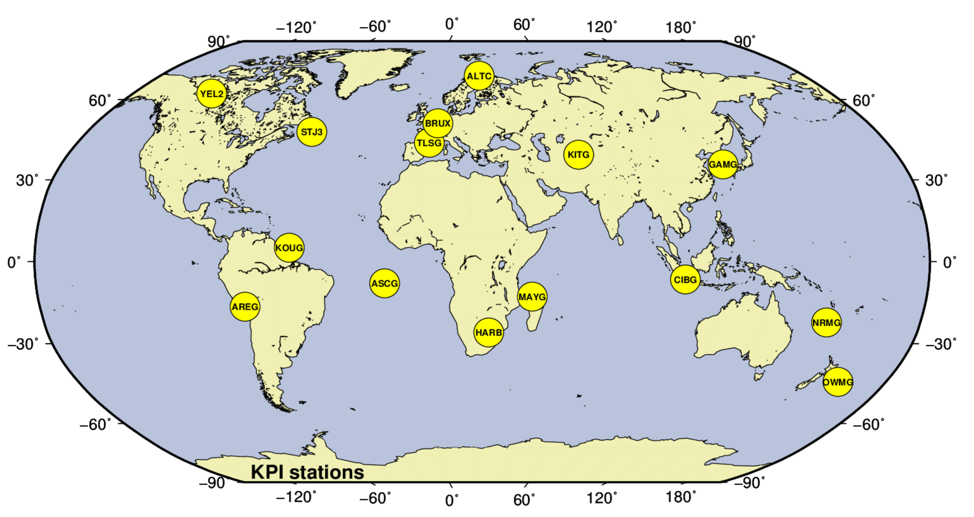

Figure 4: Global stations selected for monitoring Galileo HAS with site-positioning performance

Figures 5 and 6 demonstrate an over a year performance of the Galileo HAS IDD and indicating instances of data unavailability (either scheduled in NAGU or due to a local collection) and the accuracy of individual satellites during the period. A long-term worse performance of the satellite E12 (Fig. 5) is attributed to the use of the IGS20 PCO model in our comparison (also by reference products) which introduces a difference of about 14 cm with respect to IGS14 model used in the HAS service. A quality of the clock corrections for Galileo satellites are very consistent over the time and satellites, while these are rather variable for GPS satellites in time (Fig 6 shows temporal patterns common to all satellites). The difference can be attributed to the high quality of the Galileo on-board clocks and a low number of global stations used for the service. On October 15 [1], the performance of GPS satellites was degraded as also reported in NAGU 2023053 for 5:32-7:25 UTC). The HAS data were unavailable during January 15–17, 2024 (NAGU2024003-005). During January 18–24, HAS IDD data logging at GOP was affected [2].

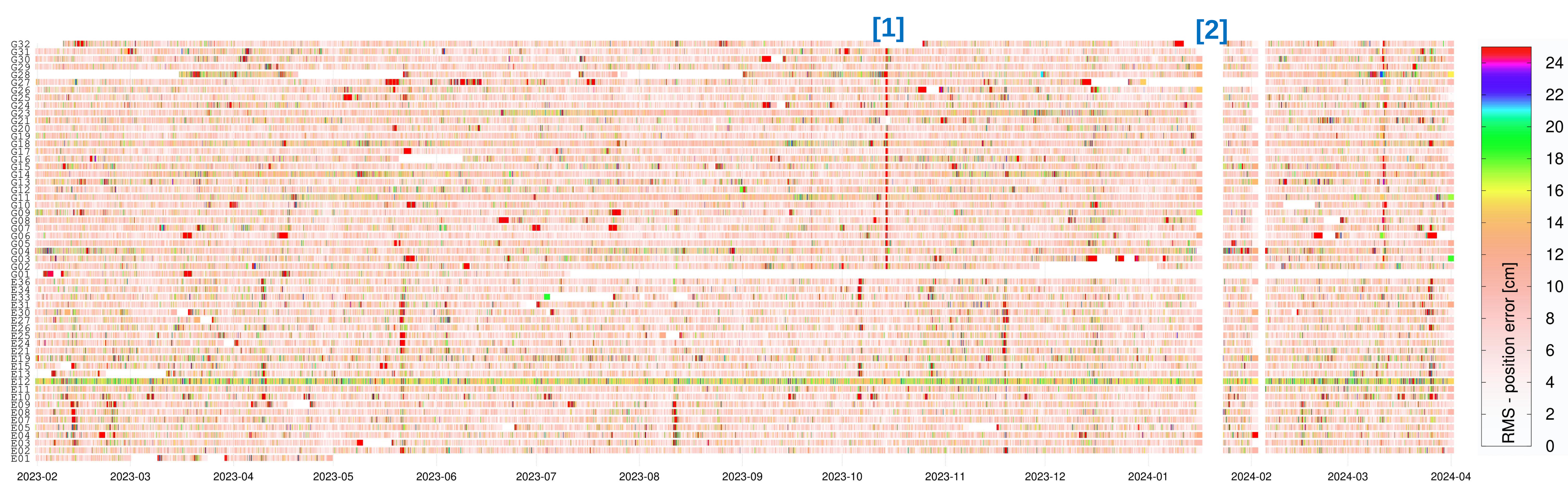

Figure 5: Day-by-day Galileo (bottom) and GPS (top) 3D satellite position statistics for HAS IDD.

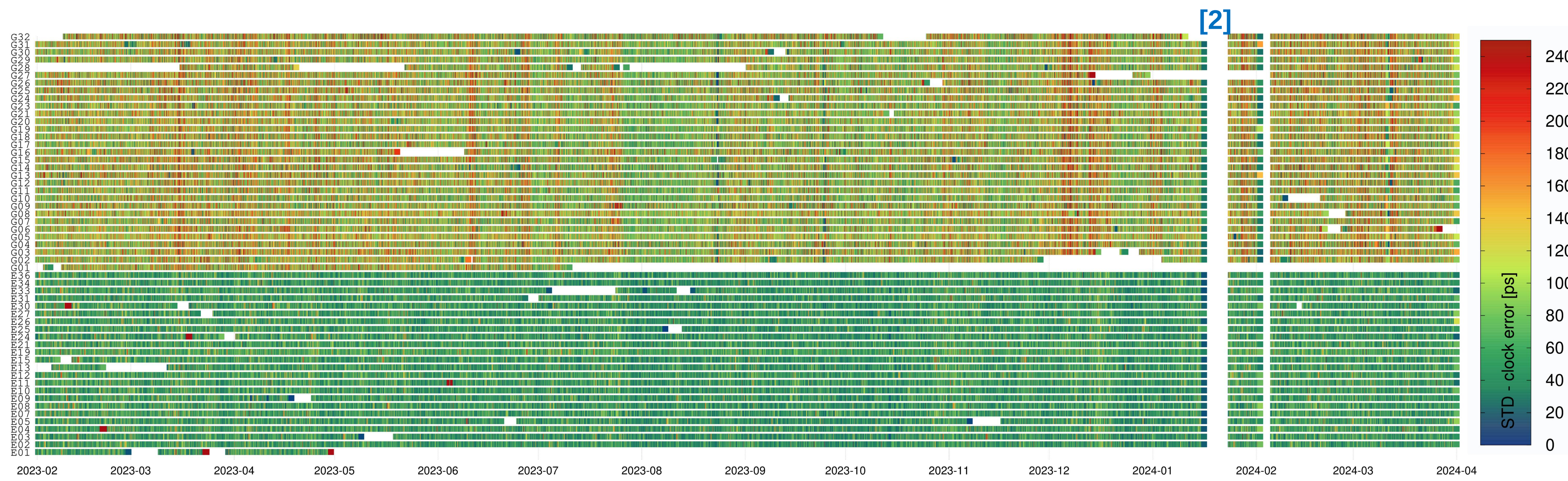

Figure 6: Day-by-dat Galileo (bottom) and GPS (top) clock corrections statistics for HAS IDD.

CONCLUSION AND FUTURE WORK

By monitoring the performance of the Galileo HAS with the G-Nut software at GOP, a long-term accuracy of Galileo and GPS satellite orbits shows a good agreement (3D RMS 7.5 cm). However, Galileo clock corrections (STD 46.6 ps) are by a factor of two more accurate compared to GPS clock corrections (STD 95.6 ps). A long-term PPP data processing demonstrates achievability of the HAS target (15/20 cm for horizontal/vertical position accuracy), although after a longer convergence time than 300s. We are enhancing the procedure to be more compliant with the last Galileo SDD (Service Definition Document) and to prepare it for a robust convergence time estimates for ambiguity-fixed positioning whenever supported with Galileo HAS too.

Table. 2: Assessment of the performance of Galileo HAS orbit and clock corrections.

GNSS	Clock [ps]	3D [cm]	Radial [cm]	Cross-track [cm]	Along-track [cm]
Galileo	46.6	7.5	2.0	3.2	5.0
GPS	95.6	7.5	2.3	3.1	4.9

Acknowledgement: We acknowledge the European Union and the European Union Agency for the Space Programme (EUSPA) for supporting the cooperation of the Galileo Reference Centre (GRC) with member states within the GEMOP project through the grant agreement NR. EUSPA/GRANT/03/2021 – „Support For Galileo/EGNOS Performance Monitoring Activities", in support of an independent monitoring of the Galileo and EGNOS service performance.