

# Multi-GNSS Pilot Project Technical Report 2024

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## 1 Introduction

All activities of the IGS Multi-GNSS Pilot Project ([MGPP](#)) contribute to the number one goal of the IGS Strategic Plan 2021+: “Achieve Multi-GNSS Technical Excellence”. In July 2024, Peter Steigenberger took over the chair of the [MGPP](#) from Oliver Montenbruck who continues to lead the IGS Combination Task Force (CTF). Kyohei Akiyama from [JAXA](#) fills the new position of the [MGPP](#) vice-chair. During the IGS Workshop in July 2024, the following recommendations have been proposed by the [MGPP](#):

1. Request GB approval for Satellite Metadata SINEX File Format 1.10.
2. Station owners are requested to transition to RINEX 4 subject to support by the receiver/conversion software.
3. Include 24:00 epoch in all IGS orbit products.
4. OPS ACs are encouraged to participate in step 3 of the BDS-3/QZSS satellite antenna calibration campaign (impact on OPS products) to include these constellations in their operational products.
5. Suggest parallel testing of the GA orbit combination software and the SPOCC orbit/clock combination software by the new ACC to consolidate multi-GNSS combination and decide on final software.
6. Establish an IGS component addressing LEO PNT.

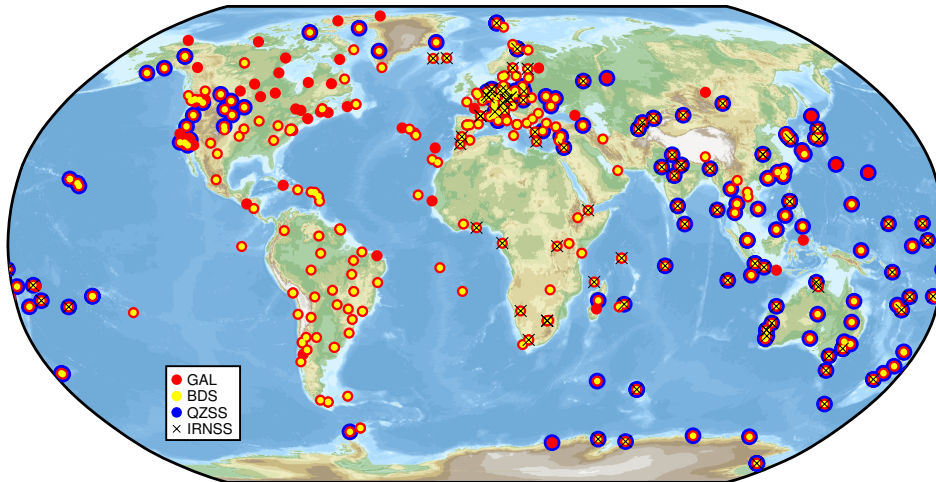
## 2 GNSS Evolution

Table 1 lists the GNSS satellite launches of the year 2024. After a break of more than two years, launches of Galileo satellites resumed. Two pairs of Galileo FOC satellites have been launched by SpaceX with its Falcon-9 rocket. The two BeiDou MEO satellites launched in September 2024 are the last spacecraft of the BeiDou-3 system. They serve as backup and for testing technologies of the next-generation BeiDou-4. The 7th GPS III satellite was launched in December 2024 and started signal transmission with PRN G01 on 28 December 2024.

**Table 1:** GNSS satellite launches in 2023.

Date	Satellite	Type
28-Apr-2024	Galileo FOC 25 and 27	MEO
17-Sep-2024	Galileo FOC 26 and 32	MEO
19-Sep-2024	BeiDou-3 M-25 and M-27	MEO
17-Dec-2024	GPS III-7	MEO

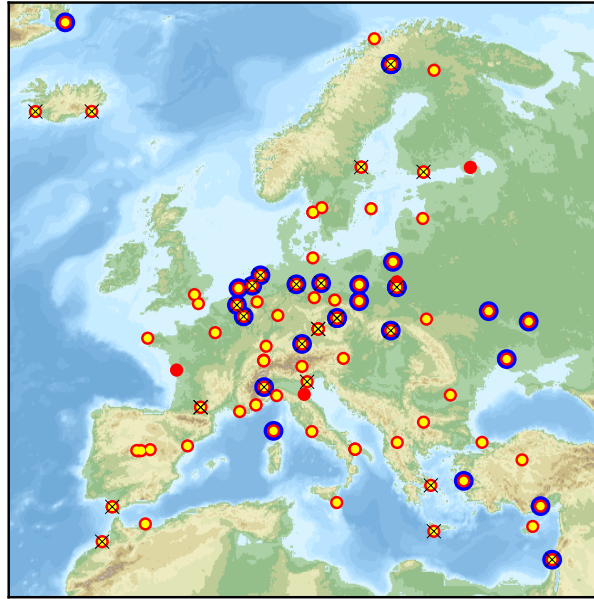
The European Union published updated receiver guidelines ([European Union, 2024](#)) for the Open Service Navigation Message Authentication (OSNMA) as well as the interface control document for OSNMA internet data distribution ([European Union, 2024](#)). Cabinet Office, Government of Japan, published the interface specification of the QZSS Navigation Message Authentication (NMA, [Cabinet Office, 2024](#)).



**Figure 1:** Distribution of IGS multi-GNSS stations supporting tracking of Galileo (red), BeiDou (yellow), QZSS (blue), and IRNSS (black crosses) as of January 2025.

### 3 Network

As of January 2025, the IGS multi-GNSS tracking network comprises 385 active stations, see Figs. 1 and 2. For the first time, this is a reduction compared to the previous year (−18 stations). Unfortunately, another two stations are completely dormant and did not provide any observations in 2024.



**Figure 2:** Distribution of European IGS multi-GNSS stations as of January 2025. See Fig. 1 for explanation of individual station labels.

### 4 Products

Table 2 lists the analysis centers (ACs) contributing orbit and clock products to the IGS Multi-GNSS Pilot Project. Changes in the MGPP products cover additional constellations and the inclusion of the midnight (24:00) epoch in orbit and clock product files. All ACs now cover the global systems GPS, GLONASS, Galileo, and BeiDou.

- Inclusion of the midnight epoch:
  - SHAO: 56/2024
  - GFZ: 186/2024
  - CNES/CLS: 196/2024 (Loyer , 2024)
- JAXA covers BDS-2 and BDS-3 in their products starting with GPS week 2334, (29-Sep-2024).

**Table 2:** Analysis centers contributing to the IGS MGPP as of December 2024.

Institution	Abbr.	GNSS
CNES/CLS	GRGOMGXFIN	GPS+GLO+GAL+BDS2+BDS3
CODE	CODOMGXFIN	GPS+GLO+GAL+BDS2+BDS3+QZS
GFZ	GFZOMGXRAP	GPS+GLO+GAL+BDS2+BDS3+QZS
IAC	IACOMGXFIN	GPS+GLO+GAL+BDS2+BDS3+QZS
JAXA	JAXOMGXRAP	GPS+GLO+GAL+BDS2+BDS3+QZS
SHAO	SHAOMGXRAP	GPS+GLO+GAL+BDS2+BDS3
Wuhan University	WUMOMGXFIN	GPS+GLO+GAL+BDS2+BDS3+QZS

Several ACs and individual members of the MGPP contribute to IGS BDS-3/QZSS satellite antenna calibration campaign. The aim of that campaign is to provide a set of BDS-3 and QZSS satellite antenna phase patterns and phase center offsets consistent with the IGS20/IGb20 reference frame in order to include these systems also in the operational IGS products. More details are given in the report of the Reference Frame Product Committee.

Multi-GNSS differential code bias (DCB) products are generated by CAS and GFZ (daily rapid products) as well as DLR (quarterly final product). The transition of the MGEX DCB products to operational (OPS) IGS products officially took place on 23 January 2024 but both ACs generating daily products provided their files in both flavors for a transition period of about eight weeks.

## 5 Satellite Metadata

A new version 1.10 of the IGS satellite metadata format has been published (Steigenberger and Montenbruck, 2024) and approved by the IGS Governing Board. The major change of this version is an additional SATELLITE/PLANE block. In addition to the orbital plane, the slot within the plane is given. This information has been requested by the IGS Combination Task Force to allow for a plane-specific grouping/weighting in the combination. The latest version of the IGS satellite metadata file is available at [https://files.igs.org/pub/station/general/igs\\_satellite\\_metadata.snx](https://files.igs.org/pub/station/general/igs_satellite_metadata.snx).

Lockheed Martin published the phase center offsets of the 6th GPS III satellite G079 (GSC, 2024). Antenna patterns for G079 are currently still missing. Antenna calibrations, spacecraft mass, center of mass, and laser retro reflector location for the first pair of Galileo FOC satellites launched in 2024 have been published by the European GNSS Service Center (GSC, 2024).

## 6 Combination Task Force

The Combination Task Force (CTF) established in the context of the [MGPP](#) continued its efforts to advance, implement, and validate concepts for combination of multi-GNSS products. Several online meetings were held in the reporting period and intermediate results were presented at the IGS Workshop in the middle of 2024. The CTF presently comprises a total of 19 members including recent additions from the Chinese Academy of Sciences. Work in 2024 included the study of algorithmic improvements and the validation of variance component estimation (VCE) based orbit combination schemes, with specific attention to the newly proposed sequential formulation. This promises more robust weighting in case of satellite-specific weight determination.

Geoscience Australia ([GA](#)) released their newly developed Robust Orbit Combination Software (ROCS) with mean absolute deviation (MAD) based weighting for public use ([Geoscience Australia, 2024](#)), and GFZ Helmholtz Centre for Geosciences ([GFZ](#)) is likewise preparing a public release of its VCE-based Satellite Precise Orbit and Clock Combination (SPOCC) software ([Mansur et al., 2024](#)). A dedicated campaign has been setup to systematically compare VCE and MAD based combination results from the two software packages using a one-year data set of multi-GNSS products from the current OPS and MGX chains of various IGS analysis centers. Based on the findings of this campaign, a recommendation for the new analysis center coordinator (ACC) can be developed concerning the software package which appears most suitable for the implementation of an operational multi-GNSS orbit and clock combination within the IGS.

### Acronyms

<b>CAS</b>	Chinese Academy of Sciences
<b>CLS</b>	Collecte Localisation Satellites
<b>CTF</b>	Combination Task Force
<b>CNES</b>	Centre National d'Etudes Spatiales
<b>CODE</b>	Center for Orbit Determination in Europe
<b>DLR</b>	Deutsches Zentrum für Luft- und Raumfahrt
<b>GA</b>	Geoscience Australia
<b>GFZ</b>	GFZ Helmholtz Centre for Geosciences
<b>IAC</b>	Information and Analysis Center for Positioning, Navigation and Timing
<b>JAXA</b>	Japan Aerospace Exploration Agency
<b>MGPP</b>	Multi-GNSS Pilot Project
<b>SHAO</b>	Shanghai Observatory
<b>WU</b>	Wuhan University

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