# 2026 IGS Workshop Recommendations

compiled 31 Aug 2026 by the IGS Central Bureau

Contributors: Kyohei Akiyama, Markus Bradke, Sharyl Byram, Michael J. Coleman, Maylis de La Serve, Bingbing Duan, Jianghui Geng, Francesco Gini, Médéric Gravelle, André Hauschild, Thomas Herring, Tobias Kersten, Andrzej Krankowski, Zishen Li, Salim Masoumi, Lotfi Massarweh, David Mencin, Patrick Michael, Rosa Pacione, Paul Rebischung, Ryan Ruddick, Axel Rülke, Peter Steigenberger, Arturo Villiger, Ningbo Wang, Qiang Wen, Guy Wöppelmann, Jian Yao, and Taylor Yates

## Table of Contents

# Analysis Centre Coordinator and Analysis Centres

Taylor Yates, Thomas Herring, Salim Masoumi

**Rapporteur(s) :** Taylor Yates, Thomas Herring, Salim Masoumi

## IGS 2021+ Strategic Plan Fulfilment

| Goals | Objectives | Status and Fulfilment |
|---|---|---|
| **Goal 1 : Multi-GNSS Technical Excellence** | Identify impediments to multi-GNSS in each working group and infrastructural component, and facilitate solutions to these blockages. | Demonstration multi-GNSS at ACC finished, operationalizing by 2027 |
| | Coordinating (and tracking progress) the various multiGNSS contributions (achievements) across all Working Groups and Infrastructural components. | MultiGNSS Combination Task Force concluded, support multiGNSS working group in testing QZSS and BDS inclusion |
| | Identify and incubate aspects of IGS component work that are in need of special attention to make a strong step toward multiGNSS. | MultiGNSS Combination Task Force concluded |
| | Advocate the benefit and critical need of Multi-GNSS through case studies, leadership, and demonstration. | Demonstration combination products available for review/analysis |
| **Goal 2 : Outreach and Engagement** | Facilitating collaborations with stakeholder organizations and groups to diversify and increase participation of IGS users and contributors. | Organizing and hosting AC meetings, continuous process |
| | Coordinating outreach to relevant agencies & institutions, to attract and promote IGS scientific and user applications. | Presenting status and progress at international conferences (AGU, EGU, etc), continuous process |
| | Incubating the next generation of IGS community members through Inclusion campaigns targeted at organizations and early career scientists. | Incorporated multiple early career scientists to ACC Operations |

| | | |
|---|---|---|
| | Advocating for standardization and interoperability essential to organizational sustainability and user community engagement. | Advocating for product uniformity and contributing to Combination Statistics Summary Format task force |
| **Goal 3 : Sustainability and Resilience** | Facilitating integration and evolution as both a collaborative research program and operational service. | Improving visualization of combined products |
| | Coordinating technological and geographical infrastructural innovation and diversity. | n/a |
| | Incubating organizational sustainability and resilience through personnel redundancy and modularity. | Incorporated new personnel to the ACC Operational team and trained them on relevant technologies and methods |
| | Advocating for open access geodetic and multi-GNSS data, products, and metadata via alignments with major United Nations frameworks and national/regional agendas. | Providing demonstration and operational multi-GNSS combined products as open access via IGS datacenters |

## Progress since the Previous Workshop

### On-Going Recommendations

| # | Recommendation / Action | Timeframe | Completion Criterion |
|---|---|---|---|
| 2024-01 | Transition to the new ACC and multi-GNSS | Transition to ACC to occur by the end of June 2026 and transition of operational combinations to multi-GNSS by June 2027 | IGS combined IGS0OPS products to be provided and maintained by NASA starting from July 2026<br><br>IGS combined multi-GNSS products IGS0DEM products switch to IGS0OPS from July 2027 |
| 2024-02 | Uniformity in IGS product intervals and epochs (including 05-min orbits, | End of 2026 (except for the second | Encouraging more ACs to provide uniform products as much as possible |

| | | | |
|---|---|---|---|
| | 30s clocks and inclusion of second mid-night epoch) | midnight of clocks) | |
| 2024-03 | BDS-3/QZSS inclusion campaign | End of 2026? | Stage 3 including evaluation of the AC products that wish to include BDS-3/QZSS in their OPS products by ACC<br>Upon successful evaluation by ACC (and RF) OPS products can include BDS-3/QZSS |

## Major Accomplishments

**Completed, near-completed or depreciated ACC Recommendations from the 2024 workshop:**

- Transition process to the new ACC, and roadmap to multi-GNSS as a priority for ACC
  - **ACC transition of the primary operations (OPS) to the new ACC is due to occur from July 2026**
  - **ACC already providing IGS0DEM multi-GNSS combinations for Final (orbit, clock, bias and reference attitude) and Ultra-Rapid (orbit) products and plans to replace OPS with DEM by July 2027**
- RF coordinator and ACC to assess ESA new products using esa23.atx to ensure the IGS products maintain providing access to ITRF2020
  - **Completed**
- ACs are encouraged to provide the second midnight (24:00) epochs in their products. ACC to include in the combined products upon provision by all ACs.
  - All Final AC orbit products and the majority of Rapid orbit products have already included the second midnight epoch in their orbit files. IGS combined multi-GNSS Final orbits already include the second midnight epoch, and OPS Final orbits to include from July 2026
- ACs are encouraged to experiment with the new PosiTim solar radiation force model, the JAXA QZSS shadow model, the FES2022b and FES2024 (soon available) ocean tide models.
  - **On-going general recommendation to test new models by ACs and may be removed from Workshop recommendations**
- ACs to consider processing LEO measurements and assess potential to include in their final set of products
  - Task transitioned to the recently established LEO-PNT working group.
- LEO PNT processing to be discussed further with a potential to create an independent working group/pilot project.
  - LEO-PNT working group created and tasks transitioned to
- ACs to consider providing individual frequency products
  - Pilot project created and tasks coordinated by the pilot project (see the new recommendations 2026-01 and 2026-02).

- Communication between Analysis Centre Coordinators, Reference Frame Coordinator and Analysis Centers. It was suggested that while having AC meetings when required, AC meetings occur at least every three to six months
    - AC meetings occur at least every three to six months.

### Discussion Highlights

- ACC on track to transition primary operations from GA to NASA from July 2026 as well as the transition to multi-GNSS
- Radoslaw Zajdel presented the summary of the multi-GNSS combination task force, which was concluded early 2026. The summary included an overview of the four different multi-GNSS combination software pieces available and their capabilities.
- Rolf Dach presented on ESA's Genesis mission and implications for the IGS GNSS analysis. The Lockheed-Martin antenna calibration including up to 30 degrees of nadir angle was discussed. The inconsistencies between L2 and L5 frequencies were also discussed. A test set of analyses was proposed to evaluate both of these issues and a few ACs expressed their willingness to participate. See recommendations 2026-01 and 2026-02.

### New Key Problems/Issues

- n/a

### New Concepts/Ideas

- n/a

### Changes to the Component's Charter, Goals, and/or Objectives

- n/a

## 2026 Workshop Recommendations

| # | Recommendation / Action | Timeframe | Completion Criterion |
|---|---|---|---|
| 2026-01 | Perform LMB20.ATX tests | by end of 2026 | Generation of solution series using the July 2025 to June 2026 time period:<br>> - L1/L2 using IGS20.ATX as reference (GPS-only)<br>> - L1/L2 using LMB20.ATX for comparison (GPS-only)<br>> - L1/L2 using LMB20.ATX limited to Block IIF and IIIA plus Galileo (E1/E5a) to have the constellation as for a GPS L5 solution; only |

| | | | |
|---|---|---|---|
| | | | stations with L5-signals (and calibrations) considered<br>> - L1/L5 using LMB20.ATX from Block IIF and IIIA plus Galileo (E1/E5a) |
| 2026-02 | Participate in Genesis IAG/ESA Combination Pilot Project | Duration of Pilot Project | Successful completion of Pilot Project |

# Antenna

Arturo Villiger, Tobias Kersten

**Rapporteur(s) :** Arturo Villiger (arturo.villiger@swisstopo.ch)

## IGS 2021+ Strategic Plan Fulfilment

| Goals | Objectives | Status and Fulfilment |
|---|---|---|
| **Goal 1 : Multi-GNSS Technical Excellence** | Identify impediments to multi-GNSS in each working group and infrastructural component, and facilitate solutions to these blockages. | n/a |
| | Coordinating (and tracking progress) the various multiGNSS contributions (achievements) across all Working Groups and Infrastructural components. | n/a |
| | Identify and incubate aspects of IGS component work that are in need of special attention to make a strong step toward multiGNSS. | Directly working on this objective. |
| | Advocate the benefit and critical need of Multi-GNSS through case studies, leadership, and demonstration. | Directly working on this objective. |
| **Goal 2 : Outreach and Engagement** | Facilitating collaborations with stakeholder organizations and groups to diversify and increase participation of IGS users and contributors. | n/a |
| | Coordinating outreach to relevant agencies & institutions, to attract and promote IGS scientific and user applications. | n/a |
| | Incubating the next generation of IGS community | n/a |

| | | |
|---|---|---|
| | members through Inclusion campaigns targeted at organizations and early career scientists. | |
| | Advocating for standardization and interoperability essential to organizational sustainability and user community engagement. | Directly working on this objective. |
| **Goal 3 : Sustainability and Resilience** | Facilitating integration and evolution as both a collaborative research program and operational service. | n/a |
| | Coordinating technological and geographical infrastructural innovation and diversity. | Supporting it, *e.g.*, by calibration comparisons. |
| | Incubating organizational sustainability and resilience through personnel redundancy and modularity. | Indirectly contributing to this objective. |
| | Advocating for open access geodetic and multi-GNSS data, products, and metadata via alignments with major United Nations frameworks and national/regional agendas. | n/a |

## Progress since the Previous Workshop

### On-Going Recommendations

| # | Recommendation / Action | Timeframe | Completion Criterion |
|---|---|---|---|
| 2024-1 | Receiver Antenna Calibration Updates: Historically, receiver antenna patterns were updated only alongside new ITRF releases. Given the extended life cycle of ITRF 2020, explore alternative methods for updating calibrations independently of ITRF updates. | 2027 | Decision how to proceed |
| 2024-2 | Disclosed Satellite Antenna Pattern: The AWG encourages the scientific community to explore the disclosed GPS and Galileo satellite antenna patterns, e.g. GNSS induced scale. (GPS-Pattern available at: Montenbruck et al., 2024, https://doi.org/10.1007/s00190-023-01809-y) | - | New Recommendation 2026-2 |

### Major Accomplishments

- Release of the IGS ANTEX Version 2.0
- Release of the igs20.atx file in the new (V2.0) and old (V1.4) ANTEX Version
- Antenna calibration campaign: publication under review (Kersten et. al)

### Discussion Highlights

- Discussion on the extensions of the PV for the GPS satellites due to the new GENESIS mission
- Discussion on the introduction of the ANTEX 2.0 and stopping the support of the ANTEX 1.4 format.

### New Key Problems/Issues

- Extensions of phase variations for GPS satellites in context of the future GENESIS mission

### New Concepts/Ideas

n/a

### Changes to the Component's Charter, Goals, and/or Objectives

n/a

## 2026 Workshop Recommendations

| # | Recommendation / Action | Timeframe | Completion Criterion |
|---|---|---|---|
| 2026-01 | Encourage users to switch from ANTEX 1.4 to 2.0. The AC will switch until the end of 2026. | End of 2026 | |
| 2026-02 | In the frame of the Genesis mission, the PV of GPS and Galileo need to be extended. In addition, the GPS BLOCK IIF satellites in the IGS20 ANTEX file do not contain L5 PCO values. To address this issue, a study group will be built to test the manufacturer PCOs for BLOCK IIF (adjusted to the IGS20 scale) and the extended PV patterns described and prepared in the relevant documentation (Montenbruck et al., 2024, | 2027 | |

| | | | |
|---|---|---|---|
| | https://doi.org/10.1007/s00190-023-01809-y). The group will be led by Rold Dach (COD) and Benjamin Männel (GFZ). The following ACs will participate: COD, GFZ, potentially GRGS, JPL, and MIT in the test campaign | | |
| 2026-03 | Acknowledge the effort made in the antenna calibration campaign and endorse the resulting recommendations to become an acknowledged IGS calibration facility. | 2026 | |

# Bias and Ambiguity Resolution

Jianghui Geng, Lotfi Massarweh

**Rapporteur :** Lotfi Massarweh

## IGS 2021+ Strategic Plan Fulfilment

| Goals | Objectives | Status and Fulfilment |
|---|---|---|
| **Goal 1 : Multi-GNSS Technical Excellence** | Identify impediments to multi-GNSS in each working group and infrastructural component, and facilitate solutions to these blockages. | BAR identifies and addresses potential impediments in the multi-GNSS/-frequency clock and bias consistency, thus including day-boundary discontinuities, incomplete AC contributions (e.g. BDS/QZSS), as well as inconsistent or missing OSBs, and ambiguity-resolution interoperability. This directly follows the 2024 unresolved issues on |

| | | |
|---|---|---|
| | | multi-GNSS phase-bias products, day-boundary continuity, Clock WG interaction, and Bias-SINEX evolution. |
| | Coordinating (and tracking progress) the various multiGNSS contributions (achievements) across all Working Groups and Infrastructural components. | BAR coordinates AC-specific and combined products, in close interaction with other bodies: WCC/ACC, Clock WG, Infrastructure, RINEX, and the more recently LEO-PNT Pilot Project. BAR has incorporated the latest developments and progress on satellite bias research, and satellite attitude models into its routine product combination mission |
| | Identify and incubate aspects of IGS component work that are in need of special attention to make a strong step toward multiGNSS. | BAR incubates combined clock/bias solutions, along with all-frequency phase biases and multi-frequency PPP-AR validation. Moreover, also aim to provide a diagnostic for code/phase bias consistency, receiver clock stability, and a potentially machine-readable combination statistic. |
| | Advocate the benefit and critical need of Multi-GNSS through case studies, leadership, and demonstration. | BAR demonstrates user impact via PPP-AR validation, AC comparisons and product combination tests. This was also presented during BAR Splinter Meeting |

| | | |
|---|---|---|
| | | (EGU2026-SPM64) by TU Wien concerning high-quality PPP-AR performance for COD/GRG/WUM and combined IGS/WCC products. |
| **Goal 2 : Outreach and Engagement** | Facilitating collaborations with stakeholder organizations and groups to diversify and increase participation of IGS users and contributors. | BAR involves ACs, combination centres, receiver/software developers, and other users. During EGU2026 SPM64 different institutions gathered such as Wuhan/WCC, CNES/GRG, ESA/ESOC, TU Delft, ESA/ESTEC and TU Wien, presenting contributions on clock/bias combination, OSBs, bias reference frames, real-time PPP-RTK, including an uncertainty evaluation and product validation. |
| | Coordinating outreach to relevant agencies & institutions, to attract and promote IGS scientific and user applications. | BAR outreach is implemented through IGS workshops, the website, public combined products, and open discussion in meetings such as EGU2026 SPM64. |
| | Incubating the next generation of IGS community members through Inclusion campaigns targeted at organizations and early career scientists. | BAR should continue to expose validation open datasets, product statistics, as well as open-source or reproducible workflows. In this way it allows the |

| | | |
|---|---|---|
| | | participation of new ACs (potentially), along with early-career scientists and research groups to contribute to PPP-AR and bias-product validation. |
| | Advocating for standardization and interoperability essential to organizational sustainability and user community engagement. | BAR directly supports standardization of OSB, phase-bias, clock-bias and Bias-SINEX conventions. Still, ESA's BREF (Bias Reference Frame) work highlights the need for more consistent code/phase bias reference frames, while GRG's OSB work highlights practical issues with continuity, daily resolution and missing signals. |
| **Goal 3 : Sustainability and Resilience** | Facilitating integration and evolution as both a collaborative research program and operational service. | BAR bridges research-level PPP-AR and bias modelling with the operational IGS product generation. The 2024 recommendation to introduce a combined clock/bias product as an official IGS satellite product remains the central operational transition item. |
| | Coordinating technological and geographical infrastructural innovation and diversity. | BAR promotes multi-AC, multi-constellation, multi-frequency and multi-latency product generation. This includes all latencies (final, rapid, ultra-rapid and eventually real-time products), with a |

| | | |
|---|---|---|
| | | validation across globally distributed IGS/MGEX stations. |
| | Incubating organizational sustainability and resilience through personnel redundancy and modularity. | BAR strengthens redundancy by encouraging more ACs to provide GPS/Galileo/BDS/QZSS and all-frequency phase-bias products. More independent AC contributions reduce dependence on single-centre products and improve robustness of clock/bias combination. |
| | Advocating for open access geodetic and multi-GNSS data, products, and metadata via alignments with major United Nations frameworks and national/regional agendas. | The IGS 2021+ plan explicitly emphasizes open multi-GNSS data, products, metadata, standardization and interoperability. Therefore, BAR supports public access to combined products, validation statistics, product metadata, and machine-readable combination diagnostics. |

## Progress since the Previous Workshop

### On-Going Recommendations

| # | Recommendation / Action | Timeframe | Completion Criterion |
|---|---|---|---|
| 2024-01 | Encourage more ACs to produce and release GPS/Galileo/BDS/QZSS phase clock/bias products. | 2026-2028 | At least one robust multi-AC contribution set for GPS, Galileo, BDS and QZSS phase-bias products, with documented validation statistics. |

| | | | |
|---|---|---|---|
| 2024-02 | Recommend the GB and ACC to introduce a combined clock/bias solution as an official IGS satellite product. | 2026-2027 | Formal GB/ACC decision; official product naming, distribution, documentation and validation page. |
| 2024-03 | Ensure continuity of orbit/clock/bias products at day boundaries and include 24:00 epochs in orbit, clock and attitude products. | 2026 | AC/ACC implementation in SP3, CLK, ATT/ORBEX and related products; validation showing reduced day-boundary discontinuities. |
| 2024-04 | Work with the Clock WG on time-scale issues associated with continuous “phase” clocks. | 2026-2027 | Joint BAR–Clock WG technical note defining clock/bias datum, phase-clock continuity and validation conventions. |
| 2024-05 | Encourage multi-frequency phase-bias products and start validation across ACs. | 2026-2028 | Pilot validation of multi-frequency/all-frequency code and phase OSBs, including arbitrary-frequency PPP-AR tests. |
| 2024-06 | Update Bias-SINEX for discontinuity information, LEO-PNT activities and additional bias-product requirements. | 2026-2027 | Draft Bias-SINEX extension proposal including discontinuity flags/events, product datum metadata, and LEO-PNT-relevant fields. |

## Major Accomplishments

- Since the 2024 workshop, the former PPP-AR pilot project & Bias and Calibration committee activities have effectively converged into the Bias and Ambiguity Resolution (BAR) framework, thus addressing the 2024 discussion on whether the Bias and Calibration committee should de facto be integrated with PPP-AR or coordinated through a dedicated bias role.

Moreover

- BAR has consolidated its scope around the joint treatment of satellite clocks, code biases, phase biases, and ambiguity resolution, rather than treating bias products and PPP-AR as two separate activities. This directly supports the 2024 objectives on clock-bias consistency, including PPP-AR interoperability, day-boundary continuity, and multi-frequency phase-bias validation.
- AC participation in phase-bias product generation has continued to mature, with the 2024 status already including BDS, QZSS, public combined-product testing, and all-frequency code/phase-bias products from Wuhan University.

- The BAR-related discussion has advanced from “availability of phase biases” toward more a product consistency, including consistency between clocks, code OSBs, phase OSBs, antenna modelling.
- CNES/CLS GRG reported daily OSB delivery for final, MGEX, rapid and ultra-rapid products, with GRG integer clocks and OSBs jointly enabling PPP-AR. New 2025–2026 GRG biases include GPS C2L and Galileo C7Q/C7X, while future extensions target additional frequencies/signals.
- GRG work has also clarified practical modelling issues relevant to BAR: use of reference-bias constraints instead of pure zero-mean conditions to improve continuity, stochastic versus constant segment modelling for different bias types, and the need for improved sub-daily resolution.
- ESA/ESOC presented the Bias Reference Frame concept, including long-term DCB stacking, automatic discontinuity detection, conversion toward consistent OSBs, and consistency between code and phase biases for PPP-AR use.
- The EGU2026 SPM64 BAR/WCC joint workshop provided a preparatory technical forum before the IGS Workshop 2026, covering BAR progress, GRG OSB products, ESA bias reference-frame concepts, uncertainty of clock and phase-bias SSR corrections, real-time joint clock/bias estimation, and user-side assessment of modern satellite products.
- The BAR discussions have identified the need to move toward combined correction-level validation, since PPP-AR users apply clocks, code biases, phase biases, antenna information and all stochastic assumptions jointly, not just as independent products.
- The user-side performance discussion showed that several modern AC products already support centimetre-level PPP-AR performance, while also exposing remaining sensitivities to 24:00 epochs, antenna calibration consistency, PWU modelling, multi-frequency support, and product metadata.
- The 2024 key recommendation on adding 24:00 epochs to orbit, clock and related products remains technically justified and has been strengthened by user-side evidence that daily-file interpolation and end-of-day discontinuities can affect PPP/PPP-AR processing.

## Discussion Highlights

BAR splinter discussion took place during EGU2026 Splinter Meeting 64 (SPM64 session).
Agenda:

- 16:15-16:20 | Opening remark
- 16:20-16:35 | Jianghui Geng (Wuhan)
  - Latest progress of BAR and WCC
- 16:35-16:50 | Guilhem Moreaux (CNES)
  - GRG OSB products: status & progress
- 16:50-17:05 | Tim Springer (ESOC/ESA)
  - Bye-bye, bias! The ESA Multi-GNSS Bias Reference Frame
- 17:05-17:20 | Lotfi Massarweh (TU Delft)
  - Uncertainty of clock+phase bias SSR corrections

- 17:20-17:35 | Dimitrios Psychas (ESA)
  - On the real-time joint determination of GNSS clocks and biases in UDUC PPP-RTK
- 17:35-17:50 | Marcus Franz Wareyka-Glaner (TU Wien)
  - Modern Satellite Products: From Application to Performance
- 17:50-18:00 | Open discussion

The BAR discussion focused on the consistency and interoperability of GNSS satellite products needed for PPP-AR users. The main topics were the consolidation of former PPP-AR and Bias/Calibration activities within the BAR framework, the consistency of satellite clocks with code and phase biases, day-boundary continuity, the use of 24:00 epochs, multi-GNSS/-frequency phase-bias products, and clearer product definitions and validation metrics.

The discussion also emphasized that PPP-AR users apply a combined set of corrections, not isolated products; therefore, satellite products should be considered jointly and consistently. The product quality assessment should increasingly focus on the combined correction ensemble and its impact on ambiguity resolution and user positioning. Several presentations showed that modern AC products already enable high-quality PPP-AR. However, the discussion also highlighted remaining inconsistencies in the bias datum definition, product continuity, antenna metadata, along with uncertainty representation (more applicable perhaps to real-time and near-real-time products).

## New Key Problems/Issues

- The transition from validated demonstration products to an official IGS combined clock/bias satellite product remains incomplete. The BAR Committee should continue to recommend a formal adoption path involving the GB, ACC and relevant product centres.
- Day-boundary discontinuities remain a critical issue for PPP-AR users. The 2024 recommendation to include 24:00 epochs in orbit, clock, attitude and related products remains valid and this should be retained.
- Clock and bias products are not independently interpretable without their datum definition. Hence, in undifferenced/uncombined PPP-RTK models, satellite products are estimable combinations; their datum must be better documented to ensure interoperability across ACs and users.
- Multi-frequency and arbitrary-frequency PPP-AR require more complete and more consistent code and phase OSBs. Current gaps remain for some constellations and/or signal components and/or AC contributions.
- Bias products often have daily resolution, while physical or instrumental events may occur within a day. Event detection, sub-daily resolution and discontinuity metadata remain open issues.
- Antenna PCO/PCV consistency and product metadata remain essential for PPP-AR, especially for uncombined processing and three-or-more-frequency use. Changes in the ANTEX files

might break backward compatibility when products and users apply inconsistent antenna models.
- Bias-SINEX needs evolution to support discontinuity/event metadata, product datum information, richer OSB descriptions, and future LEO-PNT transmitter-bias requirements.

### New Concepts/Ideas

- Prepare a BAR technical note defining product terminology, datum conventions, code/phase OSB interpretation, phase-clock consistency, IAR procedures and user-side requirements.
- Move from individual-product validation to combined correction-level validation, because PPP-AR users adopt orbits, clocks, code biases and phase biases jointly.
- Define standard BAR validation metrics, including availability, outlier rate, day-boundary jumps, clock/bias consistency, PPP-AR fixing rate, time-to-correct-fix, coordinate repeatability, etc.
- Coordinate with the Clock WG on continuous day-by-day phase-clock time-scale issues.
- Coordinate with the LEO-PNT Pilot Project on future transmitter biases, alternative frequency bands, short-arc tracking, metadata and Bias-SINEX extensions.

### Changes to the Component's Charter, Goals, and/or Objectives

n/a

## 2026 Workshop Recommendations

| # | Recommendation / Action | Timeframe | Completion Criterion |
|---|---|---|---|
| 2026-01 | Standardize BAR validation metrics for satellite orbit/clock/bias products, along with PPP-AR performance. | 2026-2027 | Agreed metrics to be published, including availability, outliers, ambiguity fixing rate, coordinate repeatability, etc. |
| 2026-02 | Improve day-boundary continuity of orbit, clock, attitude and bias products, including 24:00 epochs where applicable. | 2026 | Reduced day-boundary discontinuities demonstrated in PPP/PPP-AR validation. |
| 2026-03 | Publish BAR conventions for clock/bias datum definitions, OSB interpretation, phase clocks and PPP-AR user assumptions. | 2027 | Add an appendix to the Bias-SINEX format or other alternative solutions. |

| | | | |
|---|---|---|---|
| 2026-04 | Increase AC contributions for multi-GNSS and multi-frequency code/phase bias products, including BDS and QZSS. | 2026-2028 | More ACs, GNSS constellations and frequencies to be included in BAR validation. |
| 2026-05 | Define the path toward an official IGS combined clock/bias product for PPP-AR. | 2026-2028 | GB/ACC roadmap agreed; product naming, format, distribution and validation concept drafted. |

# Clock Products

Michael J. Coleman, Jian Yao

**Rapporteur:** Michael J. Coleman

## IGS 2021+ Strategic Plan Fulfilment

| Goals | Objectives | Status and Fulfilment |
|---|---|---|
| **Goal 1 : Multi-GNSS Technical Excellence** | Identify impediments to multi-GNSS in each working group and infrastructural component, and facilitate solutions to these blockages. | Stand by. Awaiting multi-GNSS clock combinations in the core products. |
| | Coordinating (and tracking progress) the various multiGNSS contributions (achievements) across all Working Groups and Infrastructural components. | Stand by. Attaining core multi-GNSS clock solutions requires coordination with the ACC. |
| | Identify and incubate aspects of IGS component work that are in need of special attention to make a strong step toward multiGNSS. | No active work. None can be accomplished in the clock products committee alone at present. |
| | Advocate the benefit and critical need of Multi-GNSS through case studies, leadership, and demonstration. | Currently advocating. Continue to press and support ACC towards adding constellations to the combined products. |
| **Goal 2 : Outreach and** | Facilitating collaborations with stakeholder organizations and groups to diversify and increase participation of IGS | Active, on-going. Work closely with BIPM on |

| | | |
|---|---|---|
| **Engagement** | users and contributors. | mitigating day boundary discontinuities. |
| | Coordinating outreach to relevant agencies & institutions, to attract and promote IGS scientific and user applications. | Continuing. Admitted new representative from Thailand IGS station that duals as a UTC(k). Expands inter-disciplinary station list and geographic distribution of UTC infrastructure. |
| | Incubating the next generation of IGS community members through Inclusion campaigns targeted at organizations and early career scientists. | No work at present. |
| | Advocating for standardization and interoperability essential to organizational sustainability and user community engagement. | Continuing work. Aiming to update file format and advocate for a new calibration format. |
| **Goal 3 : Sustainability and Resilience** | Facilitating integration and evolution as both a collaborative research program and operational service. | Not at present. |
| | Coordinating technological and geographical infrastructural innovation and diversity. | Extending membership. |
| | Incubating organizational sustainability and resilience through personnel redundancy and modularity. | Maintaining vice chair role who attended the BIPM meetings in lieu of the chair in September 2025. |
| | Advocating for open access geodetic and multi-GNSS data, products, and metadata via alignments with major United Nations frameworks and national/regional agendas. | Not participating at present. |

## Progress since the Previous Workshop

### On-Going Recommendations

n/a

### Major Accomplishments

- Establish link with ACC for clock exchange processing in IGS rapid and final products.

### Discussion Highlights

- Main focus of this meeting is a presentation of the new Clock Exchange format. The details have been mostly ironed out, so the majority of the meeting consisted of a presentation of these points by M. Coleman. There were a few points of input from the members.
- Members generally recommend maintaining .CLK suffix for the new format. Users will need to read the top line of the header to determine whether the file is Clock Rinex for Clock Exchange.
- Jian Yao offered to write a file converter between the Clock Rinex and Clock Exchange formats.

### New Key Problems/Issues

- Timing and UTC community are actively looking for a machine readable format to transfer station receiver calibration measurements. Presently, these are measured and assessed during calibration campaigns, but are not stored in any of the IGS formats.
- G. Tagliaferro made a proposal to the RINEX working group to include these values in the RINEX header, but that was met with some concern from that group. Other options including the Clock Exchange or SINEX formats are being considered to include these measurements.
- GPS is discussing an end to L2 P signal and this might lead some Analysis centers to consider L1/L5 dual frequency combinations. Unfortunately, GPS Block IIF have L2C but not L1C. This is important for clock products as delays through the receiving chain will affect the station clock solutions. It was noted that ACs might decide to have different processing and this will affect the ACC, not just clock products. Coordination is needed for this.

### New Concepts/Ideas

- Recommendation to add a new working group for continuous clock products, specifically at the processing day boundary. This would require input from ACs, the PPP-AR group and several other key members of the IGS that are involved in the clock combination generation.

### Changes to the Component's Charter, Goals, and/or Objectives

- There were no changes to the Clock Products Committee charter, but an update is needed from the chair and vice-chair since it has been since 2019 when this component was still a working group.

## 2026 Workshop Recommendations

| # | Recommendation / Action | Timeframe | Completion Criterion |
|---|---|---|---|

| | | | |
|---|---|---|---|
| 2026-01 | Recommend Working Group on Continuous Clock Products to the Governing Board | Governing Board 75 | Proposed working group reviewed and adopted at the GB meeting. |
| 2026-02 | Complete the Clock Exchange Format | By Spring 2027 | Review and approval by the GB. |
| 2026-03 | Consider inclusion of receiving chain time calibration values in IGS file formats | Through 2027 | Establish which file format will host these measurements; consultation with the BIPM's working group on GNSS to follow. |
| 2026-04 | Update charter since the existing one is still written for the Clock Products Working Group and not the Clock Products Committee | By January 2027 | Reviewed and adopted by the GB. |

# Infrastructure

Markus Bradke, Ryan Ruddick

**Rapporteurs :** Markus Bradke, Ryan Ruddick, Patrick Michael, David Mencin

## IGS 2021+ Strategic Plan Fulfilment

| Goals | Objectives | Status and Fulfilment |
|---|---|---|
| **Goal 1 : Multi-GNSS Technical Excellence** | Identify impediments to multi-GNSS in each working group and infrastructural component, and facilitate solutions to these blockages. | Directly working on this objective. |
| | Coordinating (and tracking progress) the various multiGNSS contributions (achievements) across all Working Groups and Infrastructural components. | Directly working on this objective. |
| | Identify and incubate aspects of IGS component work that are in need of special attention to make a strong step toward multiGNSS. | Directly working on this objective. |
| | Advocate the benefit and critical need of Multi-GNSS through case studies, leadership, and demonstration. | Indirectly contributing to this objective. |

| | | |
|---|---|---|
| **Goal 2 : Outreach and Engagement** | Facilitating collaborations with stakeholder organizations and groups to diversify and increase participation of IGS users and contributors. | Directly working on this objective. |
| | Coordinating outreach to relevant agencies & institutions, to attract and promote IGS scientific and user applications. | Indirectly contributing to this objective. |
| | Incubating the next generation of IGS community members through Inclusion campaigns targeted at organizations and early career scientists. | Indirectly contributing to this objective. |
| | Advocating for standardization and interoperability essential to organizational sustainability and user community engagement. | Directly working on this objective. |
| **Goal 3 : Sustainability and Resilience** | Facilitating integration and evolution as both a collaborative research program and operational service. | Directly working on this objective. |
| | Coordinating technological and geographical infrastructural innovation and diversity. | Directly working on this objective. |
| | Incubating organizational sustainability and resilience through personnel redundancy and modularity. | Indirectly contributing to this objective. |
| | Advocating for open access geodetic and multi-GNSS data, products, and metadata via alignments with major United Nations frameworks and national/regional agendas. | Directly working on this objective. |

## Progress since the Previous Workshop

### On-Going Recommendations

| # | Recommendation / Action | Timeframe | Completion Criterion |
|---|---|---|---|
| 2024-03 | Develop an extensible way to categorize stations by their use for the community. | | |
| 2024-06 | Contributing to the GGOS Data and Information System Committee to ensure the improvement of FAIR GNSS data and metadata. | | |

| | | | |
|---|---|---|---|
| 2024-07 | Harmonize the code lists within the IGS station metadata. | | |

### Major Accomplishments

- Developed a policy for the inclusion and exclusion of stations.
- Developed a charter for IGS data centers.
- Established a new Pilot Project on Data Architecture.
- Improved NavIC tracking capabilities in the system footprint (6 IGS stations are able to track the full signal spectrum).

## Discussion Highlights

Tracking Network and Metadata

- Africa Engagement:
  - Work with IGS CB and UN-GGCE to develop a plan to grow the IGS Network in Africa
  - Identify gaps
  - Build partnerships with national and regional stakeholders

- Infrastructure Resilience Assessment:
  - Assessment of resilience across the infrastructure supply chain (network, data, standards)
  - Identify single points of failure and critical dependencies
  - Deliver baseline assessment to Governing Board

- Station Registry:
  - 9-character IGS station codes are not globally unique
  - The need for an authoritative, central registration entity to globally and uniquely address GNSS stations has been identified

Data Centers

- Reporting:
  - Data centers should be mandated to deliver annual (internal) reports based on a defined digital template
  - The report should include: operational metrics; information about infrastructure, IT health, and modernization; information about security and compliance; challenges, risks, bottlenecks; financial resources and future outlook

- Provenance Model:
  - The need for a data provenance model to trace back modifications on data and products to improve data quality and trust has been identified

Introduction to the newly established Pilot Project on Data Architecture

- Introduction to Pilot Project (motivation, topics, structure, deliverables)

### New Key Problems/Issues

n/a

### New Concepts/Ideas

We established a dedicated pilot project to design, build, and test a modern, API-first geodetic data infrastructure. This framework will explicitly define specifications and technical standards for next-generation data formats and programmatic APIs across the IGS ecosystem.

### Changes to the Component's Charter, Goals, and/or Objectives

n/a

## 2026 Workshop Recommendations

| # | Recommendation / Action | Timeframe | Completion Criterion |
|---|---|---|---|
| 2026-01 | Maintain a globally unique and authoritative station naming registry to ensure consistent station identification across IGS data, metadata, products, and services. | By June 2028 | • Define a standardized naming schema<br>• Define the formal governance body<br>• Develop the technical infrastructure<br>• System integration |
| 2026-02 | Encourage and support regular station hardware upgrades to maintain accurate metadata including site photos and site maintenance, as well as data quality, network reliability, and compatibility with evolving GNSS technologies and IGS requirements. | By June 2028 | • Develop an automated audit system<br>• Define tracking and upgrade metrics |
| 2026-03 | Expand outreach and capacity-building efforts in Africa to address regional network gaps and strengthen the geographic distribution of the IGS tracking network. | By June 2028 | • Define core regions of interest<br>• Adding 20-30 stations strategically located in underrepresented areas<br>• Provide education material for station operators |

| | | | |
|---|---|---|---|
| 2026-04 | Improve the traceability, transparency, and reproducibility of IGS data and products by developing, establishing and implementing data provenance standards. | By June 2028 | • Define a formalized data provenance model<br>• Create an implementation plan for data providers |
| 2026-05 | Drive accountability and continuous improvement by mandating comprehensive annual reports from all IGS Global and Regional Data Centers to rigorously track operational performance, data assets, service innovations, and critical challenges. | By June 2028 | • Establish regular meetings for data center representatives<br>• Define a unified, digital reporting template<br>• Publish a formal mandate policy |
| 2026-06 | Contribute actively to internal and external working groups on data and metadata standards to advance interoperability, harmonization, and adoption of community best practices. | continuous | • Define the formal representation for each of the bodies |

# Ionosphere

Andrzej Krankowski, Zishen Li

**Rapporteur:** Andrzej Krankowski (NDLR : 23 participants.)

## IGS 2021+ Strategic Plan Fulfilment

| Goals | Objectives | Status and Fulfilment |
|---|---|---|
| **Goal 1 : Multi-GNSS Technical Excellence** | Identify impediments to multi-GNSS in each working group and infrastructural component and facilitate solutions to these blockages. | Directly working on this objective |
| | Coordinating (and tracking progress) the various multiGNSS contributions (achievements) across all Working Groups and Infrastructural components. | Directly working on this objective |
| | Identify and incubate aspects of IGS component work that are in need of special attention to make a strong step toward multiGNSS. | Directly working on this objective |

| | | |
|---|---|---|
| | Advocate the benefit and critical need of Multi-GNSS through case studies, leadership, and demonstration. | Directly working on this objective |
| **Goal 2 : Outreach and Engagement** | Facilitating collaborations with stakeholder organizations and groups to diversify and increase participation of IGS users and contributors. | Directly working on this objective |
| | Coordinating outreach to relevant agencies & institutions, to attract and promote IGS scientific and user applications. | Directly working on this objective |
| | Incubating the next generation of IGS community members through Inclusion campaigns targeted at organizations and early career scientists. | Directly working on this objective |
| | Advocating for standardization and interoperability essential to organizational sustainability and user community engagement. | Directly working on this objective |
| **Goal 3 : Sustainability and Resilience** | Facilitating integration and evolution as both a collaborative research program and operational service. | Directly working on this objective |
| | Coordinating technological and geographical infrastructural innovation and diversity. | Directly working on this objective |
| | Incubating organizational sustainability and resilience through personnel redundancy and modularity. | Not Applicable |
| | Advocating for open access geodetic and multi-GNSS data, products, and metadata via alignments with major United Nations frameworks and national/regional agendas. | Indirectly contributing to this objective |

## Progress since the Previous Workshop

### On-Going Recommendations

| # | Recommendation / Action | Timeframe | Completion Criterion |
|---|---|---|---|
| 2024-01 | Continuation of works of new Study Group: „Ionospheric Mapping Function” | by end of 2027 | Publication of a report. |
| 2024-02 | Continuation of works of new Study Group: „ New Methodology for | by end of 2027 | Publication of a report. |

| | | | |
|---|---|---|---|
| | Combining IGS Ionospheric products” | | |
| 2024-03 | Close cooperation with the Real-Time Working Group in order to elaborate full real-time VTEC and ROTI products | always | Publication of a report. |
| 2024-04 | Continuation of cooperation with IRI, LOFAR-ERIC and ICG communities | always | Publication of a report. |

### Major Accomplishments

- Further expansion of the real-time global ionospheric maps has been achieved – currently two IGS combined real-time products are available
- ROTI Northern-hemisphere polar maps are being supplemented with products covering also Southern hemisphere and equatorial region
- A few manuscripts concerning cooperation with ILT and IRI communities have been published in high impact factor peer-reviewed journals.

## Discussion Highlights

- A progress towards the final real-time global ionospheric maps have been discussed – performance of the two independent IGS combined real-time products has been presented – readiness to launch an official product
- The final ROTI ionospheric fluctuation product development towards covering the southern hemisphere and equatorial region has been presented – readiness to launch an official product
- A progress within works of 2 new Study Groups: „Ionospheric Mapping Function” and „ New Methodology for Combining IGS Ionospheric products”
- Initiating the new methodology for creation of all combined iono products
- Initiating the process of including two new IAACs in the Iono Committee – Shanghai Astronomical Observatory (SHAO) and University of Birmingham.
- A progress within the cooperation between IGS and IRI groups regarding the development of the VTEC maps as an input for the GIRO GAMBIT system.
- Progress within simultaneous ionospheric observations with GNSS and LOFAR systems have been presented.

## New Key Problems/Issues

- IGS real-time service for global ionospheric total electron content modeling
- IGS ROTI Maps: Current Status and Its Extension towards Equatorial Region and Southern Hemisphere
- Towards Cooperative Global Mapping of the Ionosphere: Fusion Feasibility for IGS and IRI with Global Climate VTEC Maps

- Cooperation with International LOFAR Telescope (ILT) for potential synergies
- A progress within works: „Ionospheric Mapping Function" and „ New Methodology for Combining IGS Ionospheric products"

### New Concepts/Ideas

- Moving toward real-time multi-constellation ionosphere products including VTEC maps, ROTI maps, and scintillation products.
- ROTI Northern-hemisphere polar maps are being supplemented with products covering also Southern hemisphere and equatorial region (results published in six papers).
- Test launch of new combination methodology for all ionosphere products.

### Changes to the Component's Charter, Goals, and/or Objectives

n/a

## 2026 Workshop Recommendations

| # | Recommendation / Action | Timeframe | Completion Criterion |
|---|---|---|---|
| 2026-01 | Launch of official IGS RT-GIMs (rapid and final solution, autumn this year) | by end of 2026 | Publication of a report. |
| 2026-02 | Launch of official IGS ROTI maps extension towards low latitudes and Southern Hemisphere, soon | by end of 2026 | Publication of a report. |
| 2026-03 | Introduction of the new methodology for all Combined IGS Ionospheric Products, soon | by end of 2027 | Publication of a report. |
| 2026-04 | The accession process for two centers (the Shanghai Astronomical Observatory of the Chinese Academy of Sciences and the University of Birmingham) to become new IGS Ionosphere Associate Analysis Centers (IAACs) | by end of 2027 | Publication of a report. |
| 2026-05 | Continuation of work of Study Group: „Ionospheric Mapping Function" | always | Publication of a report. |
| 2026-06 | Continuation of work of Study Group: „ New Methodology for Combining IGS Ionospheric products" | always | Publication of a report. |

| | | | |
|---|---|---|---|
| 2026-07 | Continuation of cooperation with IRI, LOFAR-ERIC and ICG communities | always | Publication of a report. |

# LEO-PNT

Francesco Gini, Lotfi Massarweh

**Rapporteurs :** Francesco Gini, Lotfi Massarweh.

## IGS 2021+ Strategic Plan Fulfilment

| Goals | Objectives | Status and Fulfilment |
|---|---|---|
| **Goal 1 : Multi-GNSS Technical Excellence** | Identify impediments to multi-GNSS in each working group and infrastructural component, and facilitate solutions to these blockages. | Very initial stage, looking at technical and logistic obstacles to integrating LEO-PNT signals into IGS activities. |
| | Coordinating (and tracking progress) the various multiGNSS contributions (achievements) across all Working Groups and Infrastructural components. | The workplan foresees a coordination with all the main IGS bodies, starting with Antenna, ACs & ACC, BAR, Clock, Infrastructure, and RINEX committees. |
| | Identify and incubate aspects of IGS component work that are in need of special attention to make a strong step toward multiGNSS. | This PP considers specific works before operational adoption into IGS, incl. the format extensions, open test datasets and provider guidelines for LEO-PNT. |
| | Advocate the benefit and critical need of Multi-GNSS through case studies, leadership, and demonstration. | Case studies are built on future constellations, i.e. Xona/Pulsar, CENTISPACE, ESA/Celeste and so on. |
| **Goal 2 : Outreach and Engagement** | Facilitating collaborations with stakeholder organizations and groups to diversify and increase participation of IGS users and contributors. | This PP engages LEO-PNT providers, manufacturers, along with ACs and station |

| | | |
|---|---|---|
| | | operators. |
| | Coordinating outreach to relevant agencies & institutions, to attract and promote IGS scientific and user applications. | Call for Participation was sent, along with on-going IGS website and the first Splinter Meeting. |
| | Incubating the next generation of IGS community members through Inclusion campaigns targeted at organizations and early career scientists. | Open task forces can also involve ECS (early-career scientists), potential new ACs or emerging LEO-PNT providers. |
| | Advocating for standardization and interoperability essential to organizational sustainability and user community engagement. | Extension of current IGS standards instead of new proprietary formats. |
| **Goal 3 : Sustainability and Resilience** | Facilitating integration and evolution as both a collaborative research program and operational service. | This PP follows a 2-step approach: Exploration & Exploitation, ending with handover into operations. |
| | Coordinating technological and geographical infrastructural innovation and diversity. | It assesses extension and new developments in the IGS network, encouraging geographically diverse open datasets. |
| | Incubating organizational sustainability and resilience through personnel redundancy and modularity. | Activities are distributed across currently existing committees, but still in a very preliminary stage. |
| | Advocating for open access geodetic and multi-GNSS data, products, and metadata via alignments with major United Nations frameworks and national/regional agendas. | This PP should make open-data/metadata publication an eligibility criterion for any LEO-PNT datasets used during IGS testing. TBD… |

## Progress since the Previous Workshop

### On-Going Recommendations

n/a (LEO-PNT Pilot Project was established officially on 01 April 2026.)

### Major Accomplishments

n/a (LEO-PNT Pilot Project was established officially on 01 April 2026.)

## Discussion Highlights

The session took place with a broad range of presenters:

- 14:50: Introduction of LEO-PNT PP (F. Gini, ESA & L. Massarweh, TU Delft, 5min)
- 14:55: Receiver Manufacturer Overview (JM Sleewagen, Septentrio, 10min)
- 15:05: LEO-PNT Provider Overview: ESA Celeste (F.C. Grec, ESA, 10min)
- 15:15: LEO-PNT Provider Overview: CENTISPACE (W. Li, Wuhan, 10min)
- 15:25: RINEX for LEO-PNT (O. Montenbruck, DLR, 10min)
- 15:35: Discussion
- 16:00: Closeout

The main discussion focuses on the status of existing/planned constellations, e.g. ESA/Celeste & CENTISPACE, along with manufacturer involvement, e.g. Septentrio. Lastly, focus was given on the current critical need of extending formats, i.e., starting from RINEX as well as ANTEX, ORBEX, SP3, and so on.

An important part of the discussion centred on the provider metadata and open-data requirements, along with station/network capability to track LEO-PNT. Lastly, the availability of on-board GNSS measurements was also discussed as one uncertain aspect for the (future) integration into IGS operations.

## New Key Problems/Issues

Some principal issues are:

- lack of public ICDs for some systems;
- limitations in existing IGS formats for future LEO mega-constellations;
- limited open tracking data, also due to short LEO passes and fast geometry changes;

along with

- unclear eligibility criteria for admitting LEO-PNT data into IGS workflows.

## New Concepts/Ideas

For example:

- Establish LEO-PNT provider guidelines, including a format-dedicated task force;
- IGS-internal integration guidelines based on current provider information;
- Potentially open test-dataset campaigns, especially for a preliminary verification.

### Changes to the Component's Charter, Goals, and/or Objectives

n/a

## 2026 Workshop Recommendations

| # | Recommendation / Action | Timeframe | Completion Criterion |
|---|---|---|---|
| 2026-01 | Contact current LEO-PNT providers and receiver manufacturers to assess status and/or plans for future constellations and tracking capabilities. | by end of 2026 | Integration of information in the LEO-PNT Pilot Project website. |
| 2026-02 | Coordinate LEO-PNT extensions of existing IGS formats, prioritising RINEX, then SP3/ORBEX, along with Clock RINEX, Bias-SINEX and ANTEX. | by summer 2027 | List of format-extension issues, including proposed change requested to be submitted to relevant format committees. |
| 2026-03 | Collect first LEO-PNT test open data and perform preliminary integration tests in collaboration with ACs and Pilot Project core members. | by summer 2027 | Potential publication or dedicated meetings for presenting these new results. |

# Multi-GNSS

Peter Steigenberger, Kyohei Akiyama

**Rapporteur:** Peter Steigenberger

### IGS 2021+ Strategic Plan Fulfilment

| Goals | Objectives | Status and Fulfilment |
|---|---|---|
| **Goal 1 : Multi-GNSS Technical Excellence** | Identify impediments to multi-GNSS in each working group and infrastructural component, and facilitate solutions to these blockages. | under progress |
| | Coordinating (and tracking progress) the various multiGNSS contributions (achievements) across all Working Groups and Infrastructural components. | under progress |

| | | |
|---|---|---|
| | Identify and incubate aspects of IGS component work that are in need of special attention to make a strong step toward multiGNSS. | under progress |
| | Advocate the benefit and critical need of Multi-GNSS through case studies, leadership, and demonstration. | under progress |
| **Goal 2 : Outreach and Engagement** | Facilitating collaborations with stakeholder organizations and groups to diversify and increase participation of IGS users and contributors. | n/a |
| | Coordinating outreach to relevant agencies & institutions, to attract and promote IGS scientific and user applications. | n/a |
| | Incubating the next generation of IGS community members through Inclusion campaigns targeted at organizations and early career scientists. | n/a |
| | Advocating for standardization and interoperability essential to organizational sustainability and user community engagement. | n/a |
| **Goal 3 : Sustainability and Resilience** | Facilitating integration and evolution as both a collaborative research program and operational service. | n/a |
| | Coordinating technological and geographical infrastructural innovation and diversity. | n/a |
| | Incubating organizational sustainability and resilience through personnel redundancy and modularity. | under progress |
| | Advocating for open access geodetic and multi-GNSS data, products, and metadata via alignments with major United Nations frameworks and national/regional agendas. | under progress |

## Progress since the Previous Workshop

### On-Going Recommendations

| # | Recommendation / Action | Timeframe | Completion Criterion |
|---|---|---|---|
| 2022-04 | Study options for supporting the GPS L1/L5 user community through dedicated IGS clock or bias products | By end of 2026 | Decision on way forward regarding GPS L1/L5 products |

| | | | |
|---|---|---|---|
| 2024-02 | Station owners are requested to transition to RINEX 4 subject to support by the receiver/conversion software | ASAP | All IGS RINEX files in format version 4.0x |
| 2024-04 | 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 | By end of 2026 | Inclusion of BDS-3/QZSS in operational AC products |

### Major Accomplishments

- All MGEX ACs cover BDS-3 and Galileo with their products, 50 % cover QZSS
- Step 2 of the IGS BDS-3/QZSS satellite antenna calibration campaign completed, new antenna models included in igs20.atx
- Coordinated signal switches of MGEX ACs for QZSS (L1C/A and L2 to L1C and L5) and BDS-3 (B1I and B3I to B1C and B2a)
- Successful termination of the IGS combination task force

## Discussion Highlights

- Seven MGEX and legacy ACs agreed to participate in step 3 of the IGS BDS-3/QZSS satellite antenna calibration campaign.
- QZSS current status and future plans by Satoshi Kogure: launch of QZS-7 in 2026, two further satellites are currently built.
- NavIC current status and future plans by Neelu Rathi: ISRO currently provides six regional dual-frequency capable NavIC stations to the IGS; extension to a global network is planned for the next few years.
- The responsibility for the maintenance of the IGS satellite metadata file will be transferred to the SVOD Committee.
- There is currently no interest of the MGEX ACs in dedicated studies on GLONASS CDMA.

## New Key Problems/Issues

- The MGEX ACs consider the current number of IGS stations that provide dual-frequency NavIC observations too small. They will not start processing NavIC before a reasonable number of stations is available.
- GLONASS L1 and L2 CDMA tracking is currently not supported by the IGS network due to missing manufacturer support (receiver firmware or RINEX conversion software).

### New Concepts/Ideas

- Include metadata of GNSS secondary antennas (e.g., CDMA antenna of GLONASS M+, L1S and L5S antennas of QZSS) in igs20.atx and igs_satellite_metadata.snx.

### Changes to the Component's Charter, Goals, and/or Objectives

- Due to the remaining tasks, in particular the inclusion of NavIC, the activities of the MGPP should be extended beyond the current plan for termination of the PP (operational availability of combined multi-GNSS orbit and clock products, mid of 2027).

## 2026 Workshop Recommendations

| # | Recommendation / Action | Timeframe | Completion Criterion |
|---|---|---|---|
| 2026-01 | Legacy and MGEX ACs are encouraged to participate in step 3 of the BDS/QZSS satellite antenna calibration campaign (impact on products). | by end of 2026 | Inclusion of BDS-3/QZSS in operational AC products |
| 2026-02 | MGEX ACs are encouraged to include NavIC in their products. | by end of 2028 | Inclusion of NavIC in MGEX products |
| 2026-03 | IGS station operators should support NavIC L1 and GLONASS CDMA tracking by firmware updates and enabling these signals. | ASAP | Improved tracking coverage of these signals |
| 2026-04 | GNSS system providers are asked to provide missing metadata of current and future satellites. | ASAP | Public availability of missing metadata |
| 2026-05 | Metadata of secondary antennas like GLONASS CDMA and QZSS L1S/L5S should be included in operational IGS files. | by end of 2026 | Inclusion in:<br>igs20.atx<br>igs_satellite_metadata.snx<br>Satellite metadata format |

# Real-Time

Axel Rülke (BKG), Ningbo Wang (CAS)

**Rapporteurs :** Axel Rülke, Ningbo Wang

## IGS 2021+ Strategic Plan Fulfilment

| Goals | Objectives | Status and Fulfilment |
|---|---|---|
| **Goal 1 : Multi-GNSS Technical Excellence** | Identify impediments to multi-GNSS in each working group and infrastructural component, and facilitate solutions to these blockages. | Most RT ACs provide Multi-GNSS products. The only exception is NRCan, who provides GPS-only solutions. |
| | Coordinating (and tracking progress) the various multiGNSS contributions (achievements) across all Working Groups and Infrastructural components. | The RT Committee is in close collaboration with the IC committee and the ionosphere committee in order to coordinate multi-GNSS contributions. |
| | Identify and incubate aspects of IGS component work that are in need of special attention to make a strong step toward multiGNSS. | |
| | Advocate the benefit and critical need of Multi-GNSS through case studies, leadership, and demonstration. | RT committee provides multi-GNSS products for use in PPP solutions. |
| **Goal 2 : Outreach and Engagement** | Facilitating collaborations with stakeholder organizations and groups to diversify and increase participation of IGS users and contributors. | RT committee contributes to RTCM activities to promote a standarized open SSR format. Such a format is a basic requirement for the easy use of IGS RTS products for a large variety of applications. |
| | Coordinating outreach to relevant agencies & institutions, to attract and promote IGS scientific and user applications. | The RTS website is updated regularly and provides the latest information on IGS RT ACs and IGS RTS products. |

| | | |
|---|---|---|
| | | A special issue on the 10th anniversary of the IGS RTS is announced in Satellite Navigation. Contributions will be accepted until 30 May 2027. |
| | Incubating the next generation of IGS community members through Inclusion campaigns targeted at organizations and early career scientists. | |
| | Advocating for standardization and interoperability essential to organizational sustainability and user community engagement. | IGS and BKG contribute actively to RTCM Special Committee 104 promoting SSR standardization for GNSS RT PPP applications. |
| **Goal 3 : Sustainability and Resilience** | Facilitating integration and evolution as both a collaborative research program and operational service. | There are 12 RT ACs within IGS RTS. The acceptance of additional ACs and new Combination Centers will ensure the sustainability of the IGS RTS. |
| | Coordinating technological and geographical infrastructural innovation and diversity. | The current RT ACs are distributed across three continents: Europe, Asia, and North America. In the future, there might be another AC from Australia. |
| | Incubating organizational sustainability and resilience through personnel redundancy and modularity. | Chairing and Vice-Chairing are well distributed. There is more than one institution working on the combination of RT products. |
| | Advocating for open access geodetic and multi-GNSS data, products, and metadata via alignments with major United Nations frameworks and national/regional agendas. | All IGS RT products are open data and accessible through the IGS data infrastructures. |

## Progress since the Previous Workshop

### On-Going Recommendations

| # | Recommendation / Action | Timeframe | Completion Criterion |
|---|---|---|---|
| 2024-02 | Enhance IGS-SSR format by additional messages on satellite attitude, satellite offsets and satellite PCV/GDV. | by end of 2025 (original timeframe) | The recommendation could not be completed, because related efforts have primarily focused on the development of the SSR standard within RTCM. |

### Major Accomplishments

- The RTS webpage at igs.org was enhanced significantly. All ACs provide more detailed information on their products and their computation strategies. The additional contact data of key personnel was postponed due to protection of data privacy.
- An internal RT Committee assessment was conducted over a two-month test period to evaluate the selected IGS RTS products with respect to the fast 10 cm positioning accuracy. This level of performance could be confirmed for the four investigated ACs CHC, CAS, CNES and WHU.

## Discussion Highlights

- Monica Zabala Haro from Ecuador may be invited to participate in RTC
- The definition of the ambiguity-fixing rate used in RTS statistics should be clarified
- SHAO is offering an independent combination of IGS RT products
- Combination of RT AC products at IGS Real-Time Analysis Combination Center (RT-ACC)
- Introduction of HUTG: a next generation IGS combined RT-GIM via two-step global and regional correction with robust weighting from HENU and UPC-IonSAT
- Announcement of new operational ionosphere products in collaboration with the IGS ionosphere committee
- Status Update of SSR format development within RTCM SC104
- Proposal of a new IGS-SSR ionosphere RMS message

## New Key Problems/Issues

n/a

## New Concepts/Ideas

- Provide uncertainty information with IGS RT products.

## Changes to the Component's Charter, Goals, and/or Objectives

n/a

## 2026 Workshop Recommendations

| # | Recommendation / Action | Timeframe | Completion Criterion |
|---|---|---|---|
| 2026-01 | Enhance IGS-SSR format by additional messages on satellite attitude, satellite offset and satellite PCV7GDV. | by end of 2027 | Updated IGS-SSR format description document. |
| 2026-02 | Investigate the possibility of providing uncertainty information together with IGS RT products | by end of 2027 | Investigation report. |
| 2026-03 | Follow up RTCM-SSR developments and investigate potentials of the format to attract more users to the IGS RTS products. | by end of 2027 | Availability of IGS RTS RTCM-SSR products. User statistics at IGS RT products casters. |

# Reference Frame

Paul Rebischung, Maylis de La Serve

**Rapporteurs :** Paul Rebischung, Maylis de La Serve

### IGS 2021+ Strategic Plan Fulfilment

| Goals | Objectives | Status and Fulfilment |
|---|---|---|
| **Goal 1 : Multi-GNSS Technical Excellence** | Identify impediments to multi-GNSS in each working group and infrastructural component, and facilitate solutions to these blockages. | Completion of the BDS-3/QZSS satellite antenna calibration campaign, which opens the way for the integration of these constellations in the IGS operational products. |
| | Coordinating (and tracking progress) the various multiGNSS contributions (achievements) across all Working Groups and Infrastructural components. | Coordination of the BDS-3/QZSS satellite antenna calibration campaign together with the Multi-GNSS Pilot |

| | | |
|---|---|---|
| | | Project and the Antenna Committee. |
| | Identify and incubate aspects of IGS component work that are in need of special attention to make a strong step toward multiGNSS. | |
| | Advocate the benefit and critical need of Multi-GNSS through case studies, leadership, and demonstration. | |
| **Goal 2 : Outreach and Engagement** | Facilitating collaborations with stakeholder organizations and groups to diversify and increase participation of IGS users and contributors. | |
| | Coordinating outreach to relevant agencies & institutions, to attract and promote IGS scientific and user applications. | |
| | Incubating the next generation of IGS community members through Inclusion campaigns targeted at organizations and early career scientists. | |
| | Advocating for standardization and interoperability essential to organizational sustainability and user community engagement. | |
| **Goal 3 : Sustainability and Resilience** | Facilitating integration and evolution as both a collaborative research program and operational service. | |
| | Coordinating technological and geographical infrastructural innovation and diversity. | |
| | Incubating organizational sustainability and resilience through personnel redundancy and modularity. | Nomination of Maylis de La Serve as new Reference Frame Committee vice-chair. |
| | Advocating for open access geodetic and multi-GNSS data, products, and metadata via alignments with major United Nations frameworks and national/regional agendas. | |

## Progress since the Previous Workshop

### On-Going Recommendations

| # | Recommendation / Action | Timeframe | Completion Criterion |
|---|---|---|---|
| 2022-01 | Understand higher precision of TUG station position estimates compared to other ACs. | indefinite | Other ACs are able to provide station position estimates as precise as TUG's. |
| 2022-02 | Aim at further reducing spurious periodic signals in IGS station position time series, by further advances in orbit and tide modeling. | indefinite | Substantial reduction of spurious periodic errors in IGS station position time series. |
| 2022-03 | Investigate terrestrial scale [rate] differences between GNSS and the other space geodetic techniques. | indefinite | Scale discrepancies between GNSS and SLR/VLBI are resolved. |
| 2024-01 | ACs are encouraged to experiment with the new PosiTim solar radiation force model, the JAXA QZSS shadow model, the FES2022b and FES2024 (soon available) ocean tide models. | indefinite | The new models are evaluated by ACs. |
| 2024-02 | ACs are encouraged to consider processing LEO measurements and assess potential to include in their final set of products. | indefinite | LEOs are included in the final products of certain ACs. |
| 2024-03 | ACs are encouraged to consider providing individual frequency products. | indefinite | Multi-frequency products are provided by certain ACs. |

### Major Accomplishments

- Nomination of Maylis de La Serve as new Reference Frame Committee vice-chair.
- Adoption of the first two annual updates of ITRF2020 (ITRF2020-u2023 and ITRF2020-u2024) for the alignment of the IGS products, in the form of the "IGb20" (IGSMAIL-8543) and "IGc20" (IGSMAIL-8634) reference frames.
- Completion of the BDS-3/QZSS satellite antenna calibration campaign and integration of the results in igs20.atx.
- Development of new services on https://webigs-rf.ign.fr:
    - Monitoring of satellite z-PCO estimates (https://webigs-rf.ign.fr/zpco).
    - API for the computation of possible co-seismic displacements (https://webigs-rf.ign.fr/api/doc/#/Seismic/post_coseismic_request).

## Discussion Highlights

- Roadmap for ACC transition from GA/MIT to NASA GSFC does not raise major questions or concerns.
- WCC update (Qiang Wen):
  - Final & rapid multi-GNSS orbit/clock/bias combination running since 2025/03.
  - Day-boundary discontinuities mitigated in final combined products.
  - PPP-AR validation results of the same quality as with ACC combined products.
  - Ultra-rapid multi-GNSS orbit/clock combination running since 2026/05 (with ~1 week delay).
- Update from the IGS Task Force for the format standard of combination statistics (Qiang Wen):
  - YAML format reaches consensus.
  - Draft format description sent out for review.
  - Target for finalization of the format: end of 2026.
- Final update from the IGS Combination Task Force (Radosław Zajdel)
  - Review of existing software and strategies for multi-GNSS orbit/clock/bias combination.
  - Products combined with different software packages (ROCS, SPOCC, SparkCombo) and PPP-AR validation results show great consistency.
  - Review of options available for operational multi-GNSS orbit/clock/bias combination by ACC.
- Reference Frame Committee update (Paul Rebischung):
  - Review of latest major accomplishments (see list above).
  - Preliminary results from ITRF2020-u2025 analysis do not point to an urgent need to update the ITRF2020 origin and scale. Annual updates of ITRF2020 may continue for the time being.
- Transition from GPS L1/L2 to L1/L5? (Rolf Dach):
  - What should the IGS do when GPS P(Y) code is switched off? Switching from L1/L2 to L1/L5 seems a natural way forward. But…
  - What would be the impact on station positions and the reference frame?
  - Which antenna phase center corrections could be used for the GPS IIF satellites? Those from Montenbruck et al. (2024)?
  - Need to organize a test campaign before proposing a possible transition plan.
- Remaining points of discussion adjourned to the next online ACs meeting.

## New Key Problems/Issues

The main open issue discussed during the meeting was the possible future transition of the IGS analyses and products from the GPS L1/L2 ionosphere-free linear combination to L1/L5. This transition seems a natural way forward for several reasons (stronger L5 signals, compatibility with other GNSS, upcoming decommissioning of P(Y) code). However, the transition to L1/L5 raises a number of questions, including:

- What would be the impact on station coordinates, and how to adapt the IGS reference frame? An impact has to be expected at least from the switch from L1/L2 to L1/L5 ground antenna calibrations. A new reference frame would therefore be needed, whose definition strategy will depend on the prevalence and amplitude of the impacts on individual reference frame station coordinates.
- Which antenna phase center corrections could be used for the GPS IIF satellites? An option could be those compiled by Montenbruck et al. (2024) in “lmb20.atx”.
- What to do with stations that do not observe GPS L5?

To address these questions and devise a possible transition plan to GPS L1/L5, the idea of a GPS L1/L5 test campaign emerged.

### New Concepts/Ideas

n/a

### Changes to the Component’s Charter, Goals, and/or Objectives

n/a

## 2026 Workshop Recommendations

| # | Recommendation / Action | Timeframe | Completion Criterion |
|---|---|---|---|
| 2026-01 | Contribute to GPS L1/L5 test campaign by evaluating the impact of a possible switch to GPS L1/L5 on station positions and reference frame. | To be decided | Definition (or abandonment) of a transition plan of IGS operational products to GPS L1/L5. |
| 2026-02 | Work with Antenna Committee on a procedure to integrate new multi-GNSS ground antenna calibrations in igs20.atx. | To be decided | Integration of new multi-GNSS ground antenna calibrations in igs20.atx. |
| 2026-03 | Evaluate test solutions from ACs willing to integrate BDS-3 and/or QZSS in their operational products. | At ACs’ requests | BDS-3 and QZSS are included in operational AC products. |
| 2026-04 | Contribute to finalising the new format for combination statistics and implement it as output of the IGS SINEX combinations. | 2027 | Implementation of the new format in the IGS SINEX combinations. |

# RINEX

Francesco Gini, André Hauschild

**Rapporteur(s) :** Francesco Gini

## IGS 2021+ Strategic Plan Fulfilment

| Goals | Objectives | Status and Fulfilment |
|---|---|---|
| **Goal 1 : Multi-GNSS Technical Excellence** | Identify impediments to multi-GNSS in each working group and infrastructural component, and facilitate solutions to these blockages. | No impediments, RINEX fully supports multi-GNSS. |
| | Coordinating (and tracking progress) the various multiGNSS contributions (achievements) across all Working Groups and Infrastructural components. | Stations operators are required to upgrade to RINEX 4.02 to fully support NavIC tracking. All WG and IC were informed. |
| | Identify and incubate aspects of IGS component work that are in need of special attention to make a strong step toward multiGNSS. | Promote RINEX 4.02 to station operators for NavIC tracking. |
| | Advocate the benefit and critical need of Multi-GNSS through case studies, leadership, and demonstration. | |
| **Goal 2 : Outreach and Engagement** | Facilitating collaborations with stakeholder organizations and groups to diversify and increase participation of IGS users and contributors. | |
| | Coordinating outreach to relevant agencies & institutions, to attract and promote IGS scientific and user applications. | RINEX includes already members of multiple agencies and institutions. |
| | Incubating the next generation of IGS community members through Inclusion campaigns targeted at organizations and early career scientists. | Continuous discussions and collections of RIENX requirements from multiple organizations, including ones that not yet RIENX members. |
| | Advocating for standardization and interoperability | Continuous discussions |

| | | |
|---|---|---|
| | essential to organizational sustainability and user community engagement. | and collections of RIENX requirements from multiple organizations, including ones that not yet RIENX members. |
| **Goal 3 : Sustainability and Resilience** | Facilitating integration and evolution as both a collaborative research program and operational service. | RINEX committee will supports the new Architecture Pilot Project |
| | Coordinating technological and geographical infrastructural innovation and diversity. | |
| | Incubating organizational sustainability and resilience through personnel redundancy and modularity. | RINEX committee has a chair and co-chair who are both fully aware of the activities and their status. |
| | Advocating for open access geodetic and multi-GNSS data, products, and metadata via alignments with major United Nations frameworks and national/regional agendas. | As RINEX committee we continuously advocate open data policy, but we only handle the format standard not the files themselves and their related policy |

## Progress since the Previous Workshop

### On-Going Recommendations

| # | Recommendation / Action | Timeframe | Completion Criterion |
|---|---|---|---|
| 2024-01 | LEO PNT: IGS shall answer the question: should IGS get involved in the LEO PNT activities? (possibly by end 2024/early 2025).<br>If Yes, this will impact IGS at all levels (e.g., formats, Acs, RFs) and will need quite some work and coordination and will potentially require dedicated Pilot Project/Projects? | LEO-PNT: start in 2024-2025 | Investigate on IGS needs and challenges for what concerns the LEO-PNT technology |

| | | | |
|---|---|---|---|
| 2024-02 | RINEX evolution: RINEX needs a format evolution for AI and Cloud Computing applications. This requires IGS to agree on a way forward for a format evolution. Coordination between RINEX and Infrastructure Committees is needed and will potentially require a new dedicated Pilot Project. | RINEX evolution: start in 2025 | Investigate IGS needs for new architectural schemes to store GNSS data in a more effective way. |

### Major Accomplishments

- NavIC tracking (dual frequency signals handling) and handling of multiple navigation messages types (via subtypes) implemented.
- Routines update to account for GNSS ICDs updates
- Task 2024-01 can be closed – LEO-PNT Pilot Project has been created.
- Task 2024-02 can be closed – New architectural Pilot Project has been created.

### Discussion Highlights

- Discussion on handling of GNSS Receiver Hardware delays necessary to the timing community.
- Way forward to account for LEO-PNT systems

### New Key Problems/Issues

- Consolidate implementation of GNSS Receiver hardware delays: either in RINEX or SINEX.
- Start activities for updating RINEX to cover LEO-PNT data.
- Work forward towards a new architecture to store RINEX data in a more efficient way.

### New Concepts/Ideas

n/a

### Changes to the Component's Charter, Goals, and/or Objectives

n/a

## 2026 Workshop Recommendations

| # | Recommendation / Action | Timeframe | Completion Criterion |
|---|---|---|---|
| 2026-01 | Define a new ICD (RINEX 5.) to support LEO-PNT technology | by end of 2027 | Release of RINEX 5.0 format. |

# Satellite Vehicle Orbit Dynamics

Bingbing Duan

**Rapporteur :** Bingbing Duan

## IGS 2021+ Strategic Plan Fulfilment

| Goals | Objectives | Status and Fulfilment |
|---|---|---|
| **Goal 1 : Multi-GNSS Technical Excellence** | Identify impediments to multi-GNSS in each working group and infrastructural component, and facilitate solutions to these blockages. | Block-specific attitude and radiation pressure modeling activities are being pursued to improve the precision and consistency of multi-GNSS products. |
| | Coordinating (and tracking progress) the various multiGNSS contributions (achievements) across all Working Groups and Infrastructural components. | |
| | Identify and incubate aspects of IGS component work that are in need of special attention to make a strong step toward multiGNSS. | |
| | Advocate the benefit and critical need of Multi-GNSS through case studies, leadership, and demonstration. | |
| **Goal 2 : Outreach and Engagement** | Facilitating collaborations with stakeholder organizations and groups to diversify and increase participation of IGS users and contributors. | |
| | Coordinating outreach to relevant agencies & institutions, to attract and promote IGS scientific and user applications. | |
| | Incubating the next generation of IGS community members through Inclusion campaigns targeted at organizations and early career scientists. | |
| | Advocating for standardization and interoperability essential to organizational sustainability and user community engagement. | Community efforts on standardized GNSS satellite attitude modeling |

| | | |
|---|---|---|
| | | are being pursued to improve consistency among software packages and users. |
| **Goal 3 : Sustainability and Resilience** | Facilitating integration and evolution as both a collaborative research program and operational service. | The SVOD Committee has initiated long-term collaborative activities on satellite attitude modeling involving multiple institutions and IGS analysis centers. |
| | Coordinating technological and geographical infrastructural innovation and diversity. | |
| | Incubating organizational sustainability and resilience through personnel redundancy and modularity. | |
| | Advocating for open access geodetic and multi-GNSS data, products, and metadata via alignments with major United Nations frameworks and national/regional agendas. | |

## Progress since the Previous Workshop

### On-Going Recommendations

n/a (The SVOD Committee was reactivated in 2025 and no active recommendations from previous workshops were carried forward.)

### Major Accomplishments

- Reactivation of the SVOD Committee in 2025.
- Establishment of a community effort on standardized GNSS satellite attitude modeling involving 24 contributors from 12 institutions and 7 IGS Analysis Centers.
- Development and ongoing validation of the **do_gnss_attitude** framework.
- Initiation of a joint campaign on the validation and application of GNSS radiation pressure models involving ESA, JPL, TUM, and CODE.
- Organization of the 2026 SVOD splinter meeting on High-precision GNSS satellite radiation pressure modeling: fundamentals, Implementations, Validation, and Applications.

## Discussion Highlights

The SVOD splinter meeting of the IGS Workshop 2026 took place on 05 June 2026 in Santiago

de Chile from 12:45-14:00 local time (UTC-4), with the possibility of online participation.

The topic of the meeting was defined as “High-precision GNSS satellite radiation pressure modeling: fundamentals, implementations, validation, and applications”. The goal of the meeting is to discuss the availability of satellite metadata, the implementation and validation of radiation pressure models, and how these models can be applied efficiently in practice.

The agenda is as follows:

- Welcome and brief introduction, *Duan, 5 min*
- GNSS satellite metadata for orbit modeling, *Steigenberger, 10 min*
- Toward standardized GNSS attitude modeling framework, *Duan, 2 min*
- SLR-based orbit validation of GPS III SV09 and SV10, *Dilssner, Springer, Gini, Schönemann, 10 min*
- Implementation of a new JPL empirical SRP model, *Ries, Kuang, Bar-Sever, Sibthorpe, 10 min*
- Importance of thermal radiation pressure modeling, *Hugentobler, Duan, 10 min*
- Acceleration lookup tables, *Duan, 3 min*
- Discussions, *all participants, 25 min*

The meeting started with a brief introduction by Bingbing Duan. It was announced that the SVOD Committee had been reactivated in 2025. The mission of the Committee is to facilitate the availability of satellite metadata, develop and validate high-precision radiation pressure models, and promote best-practice radiation pressure modeling within the community. Joint efforts on GNSS satellite attitude modeling and radiation pressure modeling are currently ongoing within the SVOD Committee to improve the precision and consistency of satellite attitude and radiation pressure implementations.

Peter Steigenberger presented the current status of GNSS satellite metadata for orbit modeling. The presentation covered the availability and completeness of satellite mass, transmit power, geometry and optical properties, maneuver events, and attitude information. The metadata is maintained by DLR/GSOC and made available through the IGS file server.

Bingbing Duan briefly introduced the ongoing GNSS attitude modeling framework, which brings together contributors from multiple institutions and IGS Analysis Centers. The motivation for this framework is the increasing number of satellite-specific attitude models required by modern GNSS constellations. The framework is intended to serve as a transparent and reproducible reference implementation and aims to improve consistency between IGS Analysis Centers, as well as between satellite product generation and user applications. This work was also presented in the S2 session of the IGS Workshop on 02 June 2026.

Florian Dilssner presented the SLR-based orbit validation results for the two new GPS III

satellites based on the ESA RnR25 radiation pressure model. While SLR residuals for GPS III SV10 were found to be relatively flat with a scatter of only a few centimeters, systematic radial orbit errors of up to 10 cm were observed for GPS III SV09. The origin of these differences is still under investigation.

Paul Ries introduced a new empirical radiation pressure model recently developed at JPL. Compared to previous JPL GSPM series, the new model is more complex but provides an improved representation of satellite orbits.

Urs Hugentobler presented recent work on thermal radiation pressure modeling for Galileo satellites developed at TUM. The results highlighted the importance of thermal effects, particularly those associated with solar panels, which may affect orbit determination at the centimeter level. Efficient application of such complex physical models was identified as an important challenge.

Following this presentation, Bingbing Duan introduced the concept of acceleration lookup tables and presented preliminary results. The motivation, current challenges, and possible implementation strategies were discussed as a potential approach for providing an efficient interface between physical radiation pressure models and orbit determination software packages.

The meeting concluded with an open discussion involving participants attending both in person and online. Topics included metadata availability, attitude modeling, validation of empirical and physical radiation pressure models, acceleration lookup tables, and future activities of the SVOD Committee.

- PS introduced that availability and completeness of GNSS satellite metadata for orbit modeling are still limited.
- BD emphasized the importance of satellite metadata and encouraged satellite manufacturers to provide more detailed information to the community.
- BD highlighted the ongoing effort on a standardized GNSS satellite attitude modeling framework within the SVOD Committee and its role in improving transparency and consistency.
- BD and PR discussed the possibility of extending the new JPL empirical radiation pressure model to Galileo and other GNSS constellations.
- UH and RD emphasized that thermal effects, particularly those associated with solar panels, are not negligible and should be considered in high-precision IGS processing.
- RD pointed out that two-dimensional acceleration lookup tables provide a useful starting point for evaluating radiation pressure models and noted that similar approaches had already been investigated within CODE.

- FG suggested that separate lookup tables for solar radiation pressure and thermal radiation pressure accelerations could be considered.
- UH suggested that one-dimensional time-dependent acceleration lookup tables may offer a more precise and generic approach and could naturally include Earth radiation pressure effects.
- BD and the participants discussed recommendations and possible future activities of the SVOD Committee.

### New Key Problems/Issues

- Limited availability of satellite metadata, particularly information required for thermal radiation pressure modeling
- Classical empirical radiation pressure models (i.e., ECOM/ECOM2) may not adequately capture all the radiation pressure effects
- GNSS satellite attitude modeling implementations differ significantly across IGS analysis centers and software packages
- Advanced empirical radiation pressure models and complex physical macro models are difficult to implement and apply consistently in independent software packages.

### New Concepts/Ideas

- Community reference implementation for GNSS satellite attitude modeling (**do_gnss_attitude**)
- Joint validation campaign for empirical and physical radiation pressure models
- Acceleration lookup tables for efficient implementation and exchange of complex radiation pressure models
- Investigation of geometry-dependent and time-dependent lookup table representations
- Potential future radiation pressure products and metadata support via acceleration tables

### Changes to the Component's Charter, Goals, and/or Objectives

n/a

## 2026 Workshop Recommendations

| # | Recommendation / Action | Timeframe | Completion Criterion |
|---|---|---|---|
| 2026-01 | Adopt the standardized GNSS attitude modeling framework as a reference implementation. | by end of 2026 | Publication of a journal paper and the GitHub repository. |
| 2026-02 | Promote "best-practice" radiation pressure modeling through continued validation and comparison of empirical and physical models | by end of 2027 | Publication of validation results and acceleration lookup tables. |

| | | | |
|---|---|---|---|
| 2026-03 | Continue testing and evaluating current dynamic models and investigate new approaches for advanced radiation pressure modeling. | always | |

# Tide Gauge

Médéric Gravelle, Guy Wöppelmann

**Rapporteur:** Médéric Gravelle

## IGS 2021+ Strategic Plan Fulfilment

| Goals | Objectives | Status and Fulfilment |
|---|---|---|
| **Goal 1: Multi-GNSS Technical Excellence** | Identify impediments to multi-GNSS in each working group and infrastructural component, and facilitate solutions to these blockages. | n/a |
| | Coordinating (and tracking progress) the various multi-GNSS contributions (achievements) across all Working Groups and Infrastructural components. | n/a |
| | Identify and incubate aspects of IGS component work that are in need of special attention to make a strong step toward multi-GNSS. | n/a |
| | Advocate the benefit and critical need of Multi-GNSS through case studies, leadership, and demonstration. | GNSS-IR for sea level measurement benefits from an improved satellite geometry and observation density (time resolution). |
| **Goal 2: Outreach and Engagement** | Facilitating collaborations with stakeholder organizations and groups to diversify and increase participation of IGS users and contributors. | Directly working on this objective |
| | Coordinating outreach to relevant agencies & institutions, to attract and promote IGS scientific and user applications. | Directly working on this objective |
| | Incubating the next generation of IGS community | Indirectly contributing to |

| | | |
|---|---|---|
| | members through Inclusion campaigns targeted at organizations and early career scientists. | this objective |
| | Advocating for standardization and interoperability essential to organizational sustainability and user community engagement. | Directly working on this objective |
| **Goal 3: Sustainability and Resilience** | Facilitating integration and evolution as both a collaborative research program and operational service. | Directly working on this objective |
| | Coordinating technological and geographical infrastructural innovation and diversity. | Directly working on this objective |
| | Incubating organizational sustainability and resilience through personnel redundancy and modularity. | n/a |
| | Advocating for open access geodetic and multi-GNSS data, products, and metadata via alignments with major United Nations frameworks and national/regional agendas. | Directly working on this objective |

## Progress since the Previous Workshop

### On-Going Recommendations

| # | Recommendation / Action | Timeframe | Completion Criterion |
|---|---|---|---|
| 2022-01 | Non-expert community needs guidelines for the understanding of jumps, drifts, non-congruent GNSS time series from individual solutions | | Recommendation from previous membership. To be confirmed with the new TIGA group. |

### Major Accomplishments

- Repro3 solutions from ULR and GFZ published in peer-reviewed journals (Männel et al., 2022; Gravelle et al., 2023). Their products have been distributed through SONEL data centre along with the JPL and NGL solutions, which comply with the same IGS-reprocessing standards.
- Sea level community appreciates SONEL service for displaying position time series and velocities from different Analysis Centres.
- New TIGA co-chairs since May 2025.
- Recruitment of new members, including the GLOSS Chair, the president of GGOS, and representatives from FIG and PSMSL.

- Preparation of a survey to better understand expectations of the tide gauge community regarding GNSS expertise. The survey should be distributed through GLOSS channels asap (GLOSS Chair action).

## Discussion Highlights

- **Guidelines**: The need for best-practice guidelines has long been recognized within TIGA and remains a key priority. Participants acknowledged the substantial work already carried out by IGS, notably through the publication of the "Guidelines for Continuously Operating Reference Stations in the IGS", which provides a solid foundation. However, there is continued demand from tide gauge operators for dedicated guidelines on GNSS installations at tide gauge sites, including precise levelling between the GNSS ARP and the tide gauge datum (benchmark).

Two components of the former TIGA charter were discussed:

- **TIGA GNSS Analysis Centres:** the requirement to maintain at least three dedicated analysis centres to ensure consistent IGS state-of-the-art reprocessing was reviewed. This requirement has proven difficult to sustain. For example, only two GNSS@TG solutions (ULR and GFZ) were delivered during the latest Repro3 campaign. The possibility of integrating coastal GNSS stations in the processing of (non-TIGA) IGS Analysis Centres was raised, though AC representatives acknowledged this was not feasible at present in the routine processing. Nonetheless, densified solutions based on IGS reprocessed products could be produced by GFZ and potentially by MIT. Additionally, Médéric informed that ULR has committed to delivering extended repro-3 compliant solutions for all GNSS@TG stations, whose data are available through SONEL using CNES-CLS IGS products within the SPOTGINS collaborative framework (Santamaria-Gomez et al., 2025).

- **TIGA Combination Centre**: The need for a centre to evaluate individual solutions and produce an official combined TIGA product was also revisited. TIGA has historically lacked such a centre or combined solution. Participants agreed that a combination at the level of daily individual solutions is not mandatory, especially as the IGS-repro campaigns can provide one. A combination at the velocity level was considered more relevant, as long-term vertical land motion is the principal quantity of interest for sea-level applications. Recent methodological developments demonstrate how such a combination can be robustly implemented (Santamaria-Gomez et al., 2024). However, no participant has yet volunteered to maintain such a product through regular updates as time series lengthen and new velocity estimates become available.

- **GNSS-IR:** GNSS Interferometric Reflectometry for sea level measurement is receiving increasing attention from the tide gauge community. It represents a potential new area where TIGA could provide expertise and best-practice guidance. Alvaro

Santamaria-Gomez presented a debrief of the ISSI forum on "Challenges and Advances in Remote Sensing of Coastal Sea Level with Ground-based GNSS-IR" co-sponsored by the GLOSS programme. Key outcomes from the Forum include:

- Low-cost antennas can outperform geodetic antennas for GNSS-IR sea level measurements.
- An antenna mounted sideways outperforms one mounted horizontally.
- The recommended configuration is a dual-antenna setup: one low-cost antenna mounted sideways for GNSS-IR sea level measurements, paired with a geodetic antenna mounted horizontally for precise positioning.
- The GNSS-IR station installation guidelines prepared by IAG WG 4.3.0 in 2019 were reviewed. A GLOSS Task Force (TF) is being established to update them in light of the experience gained since then. The revised guidelines are expected in 2026.

## New Key Problems/Issues

- Can TIGA better serve the sea-level community beyond the GNSS expert community? The needs and expectations of tide gauge operators regarding GNSS products, guidelines, station installation, levelling, and product combination remain insufficiently documented.

- The absence of a dedicated TIGA Network Coordinator since 2020 has limited the maintenance and evolution of the TIGA network, including station metadata, modernization, legacy equipment, data quality issues, levelling information, and network evolution. The current definition of TIGA-labelled stations should also be revisited.

- Limited representation of tide gauge operators and end users within TIGA. While the GLOSS Chair participates in TIGA, broader representation of operational users is needed to better capture community requirements.
- The GLOSS Working Group on Sensor Performance and Emerging Technologies currently lacks sufficient GNSS expertise to fully address emerging applications such as GNSS-IR.

- Archiving and distributing large volumes of high-rate GNSS observations (e.g., 1 Hz) required for GNSS-IR applications remains challenging, particularly considering future real-time applications such as storm surge and tsunami monitoring.

## New Concepts/Ideas

Discussions throughout the workshop suggested that TIGA could progressively evolve beyond its traditional GNSS analysis role to serve as a broader interface between the IGS and the sea-level community, providing not only GNSS products but also expertise, guidance, and support for emerging applications. The following ideas were identified to support this evolution:

- Survey the tide gauge community to identify priorities and expectations regarding GNSS products and services.

- Revisit the definition of TIGA-labelled stations to better reflect the current observing system.
- Strengthen collaboration with GLOSS through broader participation of tide gauge operators and GNSS experts.
- Develop joint activities on GNSS-IR, particularly with the GLOSS Working Group on Sensor Performance and Emerging Technologies.
- Coordinate with the RINEX Committee to address high-rate GNSS data requirements for GNSS-IR.

### Changes to the Component's Charter, Goals, and/or Objectives

- The current TIGA Charter no longer fully reflects the renewed activities and emerging role of the pilot project. However, revising the Charter is considered premature until the outcomes of the user survey and ongoing discussions help define future priorities and objectives.

## 2026 Workshop Recommendations

| # | Recommendation / Action | Timeframe | Completion Criterion |
|---|---|---|---|
| 2026-01 | Understand users' needs. Conduct the survey of the tide gauge community to identify priorities and expectations regarding GNSS products, services, and TIGA activities. | Short term | Survey completed; results analysed and presented to TIGA. |
| 2026-02 | Provide guidance. Develop best-practice guidelines for GNSS installations at tide gauge sites, including levelling between the GNSS antenna reference point (ARP) and the tide gauge datum, in coordination with GLOSS. | Medium term | Draft guidelines prepared and circulated for community review. |
| 2026-03 | Strengthen collaboration with GLOSS, particularly on emerging applications such as GNSS-IR and user support. | Ongoing | Regular exchanges established and joint activities initiated. |
| 2026-04 | Strengthen the infrastructure. Re-establish the TIGA Network Coordinator function to support maintenance and evolution of the GNSS@TG network and associated metadata. | ASAP | Network Coordinator identified and activities resumed. |

| | | | |
|---|---|---|---|
| 2026-05 | Ensure sustainable products. Identify a sustainable strategy for the production and maintenance of official TIGA velocity products, including evaluation and combination of individual solutions where appropriate. | Medium term | Roadmap established and potential contributing institutions identified. |
| 2026-06 | Prepare future data services. Evaluate long-term archiving and dissemination requirements for high-rate GNSS observations supporting GNSS-IR applications, in coordination with the IGS Working Group on RINEX. | Medium term | Requirements documented and recommendations jointly formulated with the RINEX WG. |
| 2026-07 | Review the TIGA Charter, goals, and objectives once the survey results and ongoing discussions have clarified future priorities. | Medium term | Revised Charter prepared and submitted for approval. |

# Troposphere

Sharyl Byram, Rosa Pacione

### **Rapporteur :** Sharyl Byram

### IGS 2021+ Strategic Plan Fulfilment

| Goals | Objectives | Status and Fulfilment |
|---|---|---|
| **Goal 1 : Multi-GNSS Technical Excellence** | Identify impediments to multi-GNSS in each working group and infrastructural component, and facilitate solutions to these blockages. | In progress |
| | Coordinating (and tracking progress) the various multiGNSS contributions (achievements) across all Working Groups and Infrastructural components. | Not started |
| | Identify and incubate aspects of IGS component work that are in need of special attention to make a strong step toward multiGNSS. | In progress |
| | Advocate the benefit and critical need of Multi-GNSS through case studies, leadership, and demonstration. | In progress |

| | | |
|---|---|---|
| **Goal 2 : Outreach and Engagement** | Facilitating collaborations with stakeholder organizations and groups to diversify and increase participation of IGS users and contributors. | In progress |
| | Coordinating outreach to relevant agencies & institutions, to attract and promote IGS scientific and user applications. | In progress |
| | Incubating the next generation of IGS community members through Inclusion campaigns targeted at organizations and early career scientists. | Not started |
| | Advocating for standardization and interoperability essential to organizational sustainability and user community engagement. | In progress |
| **Goal 3 : Sustainability and Resilience** | Facilitating integration and evolution as both a collaborative research program and operational service. | In progress |
| | Coordinating technological and geographical infrastructural innovation and diversity. | Not started |
| | Incubating organizational sustainability and resilience through personnel redundancy and modularity. | In progress |
| | Advocating for open access geodetic and multi-GNSS data, products, and metadata via alignments with major United Nations frameworks and national/regional agendas. | In progress |

## Progress since the Previous Workshop

### On-Going Recommendations

| # | Recommendation / Action | Timeframe | Completion Criterion |
|---|---|---|---|
| 2024-01 | Investigate multi-GNSS estimates - dependant on availability of final IGS multi-GNSS solutions | By end of 2028 | Evaluation of models estimates with respect to the operational estimates |
| 2024-02 | Investigate new models for troposphere processing | By end of 2027 | Evaluation of models estimates with respect to the operational estimates |

| | | | |
|---|---|---|---|
| 2024-03 | Compare AC troposphere estimates to IGS Final estimate | By end of 2028 | Comparison scripts regularly running and all ACs submitting files that want feedback |

### Major Accomplishments

- Averaged an additional 20 station files/day in 2025 vs 2024
- Respro3 processing started

### Discussion Highlights

- Discussion on current status of the IGS Final troposphere estimates
- Averaged an additional 20 station files/day in 2025 vs 2024
- Update on status of Repro3 processing
- Overview of planning testing of data input changes: new models and multi-GNSS

### New Key Problems/Issues

- How to integrate other GNSS constellations into final troposphere estimates?
    - Based on IGS demo products? Currently multi-GNSS ERP and clock files unavailable which are needed for PPP processing used in IGS Final troposphere estimate processing

### New Concepts/Ideas

- How to best compare tropo estimates for quality? Looking for independent validation to detect biases and jumps in the solutions
    - Compare to NWP data?( eg ERA5 or other reanalysis)
    - Compare to other techniques like VLBI?
    - Compare ACs' submitted estimates (would need to encourage all ACs to submit these, currently only some do)

### Changes to the Component's Charter, Goals, and/or Objectives

n/a

## 2026 Workshop Recommendations

| # | Recommendation / Action | Timeframe | Completion Criterion |
|---|---|---|---|
| 2026-01 | Finish Repro3 processing | by end of 2026 | Estimates evaluated and files available on IGS data servers |

| | | | |
|---|---|---|---|
| 2026-02 | Investigate desire for combination vs PPP | by end of 2026 | Committee and user feedback |
| 2026-03 | Validate and quality check estimates with independent external data such as NWP or VLBI | by end of 2028 | Appropriate independent data identified and regular comparisons executed |

# Wuhan Combination Centre

Jianghui Geng

**Rapporteur :** Qiang Wen

## IGS 2021+ Strategic Plan Fulfilment

| Goals | Objectives | Status and Fulfilment |
|---|---|---|
| **Goal 1 : Multi-GNSS Technical Excellence** | Identify impediments to multi-GNSS in each working group and infrastructural component, and facilitate solutions to these blockages. | WCC has combined GPS/GLONASS/Galileo multi-GNSS orbit/clock/bias products from multiple ACs. Through systematic quality control, consistency assessment, WCC identifies inconsistencies among AC products and exhibit the statistical results in the webpage (https://igs.org/wg/wcc) to serve as feedback to improve interoperability and product quality |
| | Coordinating (and tracking progress) the various multiGNSS contributions (achievements) across all Working Groups and Infrastructural components. | WCC has incorporated the latest developments and progress on day-boundary issues, satellite bias research, and satellite attitude models into its routine product |

| | | |
|---|---|---|
| | | combination mission |
| | Identify and incubate aspects of IGS component work that are in need of special attention to make a strong step toward multiGNSS. | WCC has established a task force to develop a standardized combination statistics format that incorporates all essential multi-GNSS product quality assessments (orbit/clock/ERP/bias) |
| | Advocate the benefit and critical need of Multi-GNSS through case studies, leadership, and demonstration. | WCC demonstrates the benefits of multi-GNSS by providing highly reliable multi-GNSS orbit, clock, and bias products that support a wide range of applications, including positioning, timing, and geoscience research |
| **Goal 2 : Outreach and Engagement** | Facilitating collaborations with stakeholder organizations and groups to diversify and increase participation of IGS users and contributors. | WCC collaborates with the BIPM Time Department to advance the resolution of day-boundary issues in GNSS-based time and frequency transfer |
| | Coordinating outreach to relevant agencies & institutions, to attract and promote IGS scientific and user applications. | The combined products generated by WCC are openly available and support a wide range of scientific applications. For example, the ESA Copernicus project has evaluated the WCC products for the precise orbit determination of Sentinel satellites |
| | Incubating the next generation of IGS community members through Inclusion campaigns targeted at | WCC contributes to community development |

| | | |
|---|---|---|
| | organizations and early career scientists. | through student supervision and active participation in IGS workshops and scientific meetings |
| | Advocating for standardization and interoperability essential to organizational sustainability and user community engagement. | WCC is working toward a standardized product assessment framework by developing a new comprehensive combination statistics format |
| **Goal 3 : Sustainability and Resilience** | Facilitating integration and evolution as both a collaborative research program and operational service. | WCC focuses on both the advancement of combination methodologies and the routine provision of combined multi-GNSS products |
| | Coordinating technological and geographical infrastructural innovation and diversity. | WCC integrates contributions from globally distributed ACs |
| | Incubating organizational sustainability and resilience through personnel redundancy and modularity. | WCC is implementing a modular software architecture and automated email monitoring system to enhance operational resilience |
| | Advocating for open access geodetic and multi-GNSS data, products, and metadata via alignments with major United Nations frameworks and national/regional agendas. | WCC fully supports the IGS open-data philosophy by providing free access to combined products, quality statistics, and associated metadata, thereby facilitating scientific research and |

| | | |
|---|---|---|
| | | societal applications worldwide |

## Progress since the Previous Workshop

### On-Going Recommendations

n/a

### Major Accomplishments

- Successfully established and operated the WCC pilot framework for the generation and evaluation of combined multi-GNSS satellite products
- Produced routine multi-GNSS ultra-rapid/rapid/final orbit, clock, and bias products using contributions from multiple ACs, supporting the robustness and consistency of the IGS product chain
- Addressed the day-boundary discontinuity issues for the combined final products by aligning satellite clock/bias products across two consecutive days
- Developed the illustration webpage at the IGS website to intuitively show the combination results
- Launched a task force to draft a more comprehensive combination statistics format

## Discussion Highlights

- Day-boundary continuity of GNSS precise products is becoming increasingly important. It is encouraging that more ACs are beginning to generate day-boundary-aligned products. To further address this issue, the WCC and Clock committees are preparing to establish a new pilot project dedicated to day-boundary consistency and to promote the routine generation of day-boundary-aligned products by ACs

## New Key Problems/Issues

- The inclusion of BDS and QZSS in the combination process remains challenging, as only a limited number of ACs currently provide products for these constellations
- Maintaining station clock continuity across day boundaries remains a challenge for meeting the stringent requirements of time and frequency transfer applications

## New Concepts/Ideas

- What changes would be required in GPS product combination if the GPS P(Y) signals switch off in future?

## Changes to the Component's Charter, Goals, and/or Objectives

n/a

## 2026 Workshop Recommendations

| # | Recommendation / Action | Timeframe | Completion Criterion |
|---|---|---|---|
| 2026-01 | Finalize the new combination statistic format | by end of 2026 | Publication of the new format |
| 2026-02 | Align station clocks across day boundaries | by end of 2027 | Publication of aligned station clock products |