International GNSS Service (IGS)

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IGS website - https://www.igs.org

1 Introduction

In 2024, the International GNSS Service (IGS) will have been fulfilling its voluntary mission for thirty years. Still today, the Service and all of its members continue to provide and advocate for freely and openly available high-precision GNSS data and products. The delivery of the IGS core products (terrestrial reference frame, satellite orbits, satellite and receiver clock corrections, atmospheric products, and associated standards) continues to drive the Service's activities. As part of its multi-GNSS excellence objective, the IGS also continues its steady transformation into a multi-GNSS service, by adding more and more multi-GNSS stations into the core IGS network and extending the legacy products provided by the analysis centers to more constellations.

The IGS operates as a Service of the IAG, and its contribution is fundamental to generating and accessing the International Terrestrial Reference Frame (ITRF). The IGS also aims to enhance the sustainability of the global/regional geodetic reference frames through intergovernmental advocacy for geodesy. To this goal, it continues to engage with our international user community as well as several partner organizations that have an interest in geodetic applications of GNSS, such as:

- the Global Geodetic Observing System (GGOS) and International Earth Rotation and Reference Systems Service (IERS), where it facilitates cost-effective geometrical linkages with and among other precise geodetic observing techniques;
- the UN Office for Outer Space Affairs International Committee on GNSS (UN OOSA ICG), where it co-chairs the working group on "Timing, Reference Frames, and Applications", the International GNSS Monitoring and Assessment (IGMA) task force, and the Disaster Risk Reduction task force;

- the UN Committee of Experts on Global Geospatial Information Management (UN-GGIM), its Subcommittee on Geodesy and the recently established UN Global Geodetic Centre of Excellence (UN-GGCE). In this context, IGS has namely supported the development of the Global Geodetic Reference Frame (GGRF) resolution.

Additionally, IGS Governing Board (GB) members participate in the governance of IAG and GGOS Bureaux, Commissions, and Working Groups, ensuring that the IGS retains its strong level of international interconnectivity, significance, and sustainability.

IGS Terms of Reference (ToR) have been deeply reviewed within the last few years and finally approved by the GB in 2023. A number of policies and guidelines of IGS components and services have been implemented in order to improve the sustainability of the Service in future and minimize potential risks. The new ToR are now closer to the structure recommended by the IAG.

2 Structure

The IGS accomplishes its mission through membership, several components and entities for governance. As of early 2024, we count over 350+ Associate Members (AMs), representing 100+ countries/regions, and 150+ contributing organizations within the IGS. Among the latter, we count 100+ agencies operating GNSS Network Tracking Stations, 6 Global Data Centers, 13 Analysis Centers, 5 Product Coordinators, 21 Associate Analysis Centers, 24 Regional/Operational & Project Data Centers, 13 Technical Working Groups, and 2 Active Pilot Projects (Fig. 1).

AMs represent the people contributing across all IGS components, ensuring balanced organizational and geographical representation. Leading the IGS, the Governing Board (GB) is composed of elected or appointed AMs who represent the core of IGS components. The GB exercises broad oversight of IGS functions and components, discusses their activities, sets policies and monitors the progress with respect to the agreed strategic plan and annual implementation plan.

Gary Johnston (Geoscience Australia) completed his service as GB Chair in May 2020. Felix Perosanz (CNES, France) then served as GB Chair until April 2023, followed by Rolf Dach (AIUB, Switzerland) up to present. For the current composition of the GB, see https://igs.org/governance-management/#governing-board.

The Central Bureau (CB) functions as the executive office of the Service, supporting all the IGS components in their day-to-day work by providing continuous management and technology. It is steered by the GB's decisions, funded by the United States National Aeronautics and Space Administration (NASA), and hosted at the Jet Propulsion Laboratory (JPL) in Pasadena, California, USA. The CB serves as the command-and-control center for tracking network operations, manages the primary IGS Information System, and supports the ongoing update of the Service's institutional structures (ToR, GB elections, internal meetings, etc.). It also represents the outward face of the Service through public outreach to the global user community and general public.

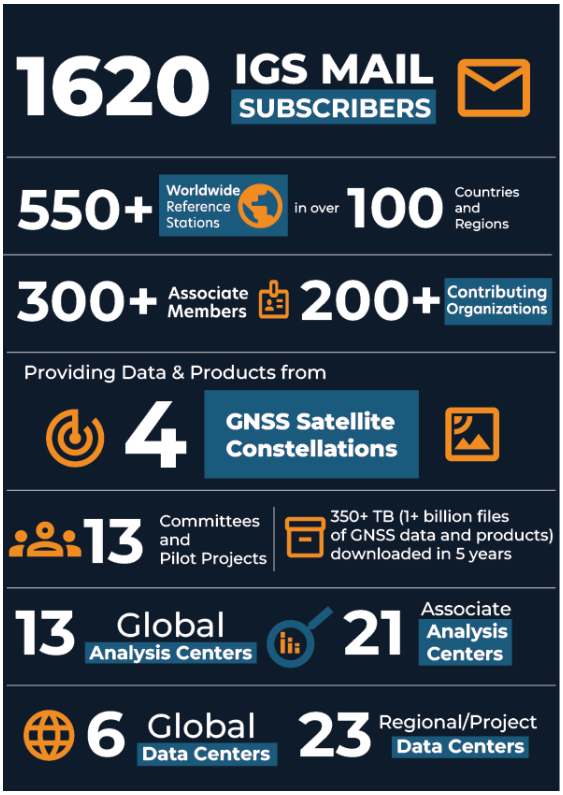

Fig. 1. "IGS at a Glance", showcasing the key numbers describing the IGS, as of April 2024. See also the IGS website https://igs.org

Allison Craddock has been the CB Director over the above mentioned period and up to present. For the current composition of the CB, see https://igs.org/governance-management/#central-bureau.

The IGS' active members are continuously and voluntarily contributing towards the IGS goals: advocacy for, development of, use of, and consistent provision of high-precision GNSS data and products.

3 IGS Network, Data and Products

The basis of the IGS is a global network of over 500 permanent and continuously operating GNSS ground stations of geodetic quality and well established monumentations. All stations track signals from GPS, and in a trend that is becoming more widespread year after year, most of them also track signals from one or more other GNSS/RNSS constellations, such as GLONASS, Galileo, BDS, QZSS, or NavIC (IRNSS). Some stations also track space-based augmentation systems (SBAS).

The IGS Network Maps at https://network.igs.org/ gives information about the current state of the IGS Network; as of April 2024, the network comprises 515 stations. Alongside the Network Map, the IGS Site Log Manager (SLM) allows station operators to securely manage and share their stations' metadata, ensuring that comprehensive and up-to-date details are available for researchers, users, and the scientific community.

The IGS Network Coordinator ensures appropriate and timely addition and decommissioning of stations in collaboration with the Infrastructure Committee, as well as regular changes to station antennas and rcvr_ant.tab file in collaboration with the Antenna Committee. The rcvr_ant.tab file contains essential information about GNSS receiver and antenna combinations utilized by IGS stations, enabling precise positioning and data interpretation, leading to enhanced compatibility, consistency, and standardization within the network for a diverse range of scientific investigations and geodetic applications.The expansion of the IGS network significantly contributed to improved coverage and geographical diversity, ensuring the availability of tracking data and products to a global user base. In particular, the continued growth and development of the network around the globe owes a lot to the numerous collaborations between the IGS and regional reference frames.

IGS data (RINEX from IGS stations) are available at the various IGS Global Data Centres (GDCs), listed at https://igs.org/data-access/#global-dcs. IGS products (terrestrial reference frames, satellite orbits, satellite and receiver clock corrections, ionospheric maps, tropospheric products, and various GNSS biases) are described and accessible at https://igs.org/products/. Some Analysis Centres started producing satellite attitude quaternions and phase biases, enabling undifferenced ambiguity resolution on a global scale. Real-Time IGS data and products are accessible through the University Corporation for Atmospheric Research (UCAR, USA) real-time caster, operational since January 2021.

There exist three lines of legacy post-processing IGS products, named as a function of the latency of their deliveries: "Final" may be released up to a week after real-time, "Rapid" is intended for daily updates, and "Ultra-rapid" products are broadcast every 6 hours. The IGS products file names follow the format described in the guidelines (https://files.igs.org/pub/resource/guidelines/Guidelines_For_Long_Product_Filenames_in_the_IGS_v2.0.pdf). In addition to post-processed products, the IGS maintains a line of real-time data and products accessible through various real-time casters.

IGS Analysis Centres are in charge of processing GNSS data and computing individual products. Some of these products are made available in the GDCs. These individual products are also merged into IGS combined products under the responsibility of the IGS Analysis Center Coordinator. The products and combined products were historically GPS-only, but are now transitioning to be fully multi-GNSS. Collectively, the IGS produces more than 700 different types of IGS Final, Rapid, and Ultra-Rapid products.

Contribution to the ITRF

The IGS' reprocessing campaigns play a pivotal role in establishing the terrestrial reference frame with utmost precision. By reanalyzing GNSS data over an extended

period, these campaigns achieve unparalleled accuracy and consistency. The results of these campaigns provide inputs to the ITRF. In turn, the IGS provides its users with the IGS realization of the ITRF, alongside updates to the associated ground and satellite antenna calibrations. This process ensures complete and reliable consistency for geodesic applications across all fields of science and society.

The Repro3 reprocessing campaign (http://acc.igs.org/repro3/repro3.html) was carried out after a decision taken at the 2018 IGS Workshop, using GPS data collected since 1994 and up to 2020. The processing standards and models have been discussed during a dedicated Analysis Center Workshop held in April 2019. The final Repro3 combined terrestrial frame solutions were provided to the IERS in April 2021 and contributed to the establishment of the 2020 release of the ITRF (ITRF2020). Subsequently, the IGS released its 2020 realization (IGS20) and the corresponding antenna calibrations (igs20.atx), which included revised values for the radial phase center offsets (PCOs) of GPS, GLONASS, and Galileo satellites, all consistent with the scale of ITRF2020.

The IGS20 is essentially an extract of ITRF2020 coordinates for a set of 332 current and historical IGS stations selected for their long-term and stable position time series. Within the IGS20 station network, a subset of 55 clusters of stations was designated as the IGS20 core network. This subset offers a homogeneous global coverage and the best possible temporal stability, and is hence recommended for the alignment of global solutions to the IGS20 reference frame.

4 Objectives and Activities (2021+)

The IGS 2021+ Strategic Plan, developed over 2020-2021 with inputs from the GB, CB, and community feedback, delineates the organization's forward-looking strategy. Released in October 2021, it encapsulates goals of achieving multi-GNSS technical excellence, strengthening outreach and engagement, and fostering sustainability and resilience. Embracing its role as a facilitator, coordinator, incubator, and advocate, the plan emphasizes the importance of maintaining leadership within the GNSS community, especially amidst growing societal demands. It strives to balance research and operational roles, promoting inclusivity, collaboration, and standardization. Its intention is to identify barriers to multi-GNSS success and to advocate for open access data through proactive measures, examples of which are detailed below. The Plan underscores a commitment to serving an expanding user base with high-quality multi-GNSS products, reflecting the collective efforts of a diverse and dedicated community. Fig. 2 summarizes the Plan.

The first Goal of the IGS 2021+ Strategic Plan is to achieve multi-GNSS technical excellence. In recent years, the IGS has made significant strides towards advancing the accuracy and reliability of multi-GNSS infrastructure, processing schemes, and product lines, paving the way for complete exploitation of new signals and constellations in navigation, surveying, geodesy, and remote sensing. The Service continually improves on that front. An example of this is the transition of the IGS raw data products to the RINEX 4 format, released in 2021 in collaboration with the Radio Technical Commission for Maritime Services - Special committee 104 (RTCM-SC104). Since then,

the IGS is actively coordinating the transition to the new format that allows a full representation of all GNSS constellations, signals and observations. The effort is supported by the CB, which advocates for the inclusion or conversion of receivers capable of multi-GNSS tracking and real-time casting.

IGS also looks outward to other techniques through its participation in the GGOS, which has illuminated how SLR observations of GNSS satellites, as well as GNSS observation of non-GNSS satellites, can play a key role in improving our understanding of observational errors and thus drive further improvement of IGS products.

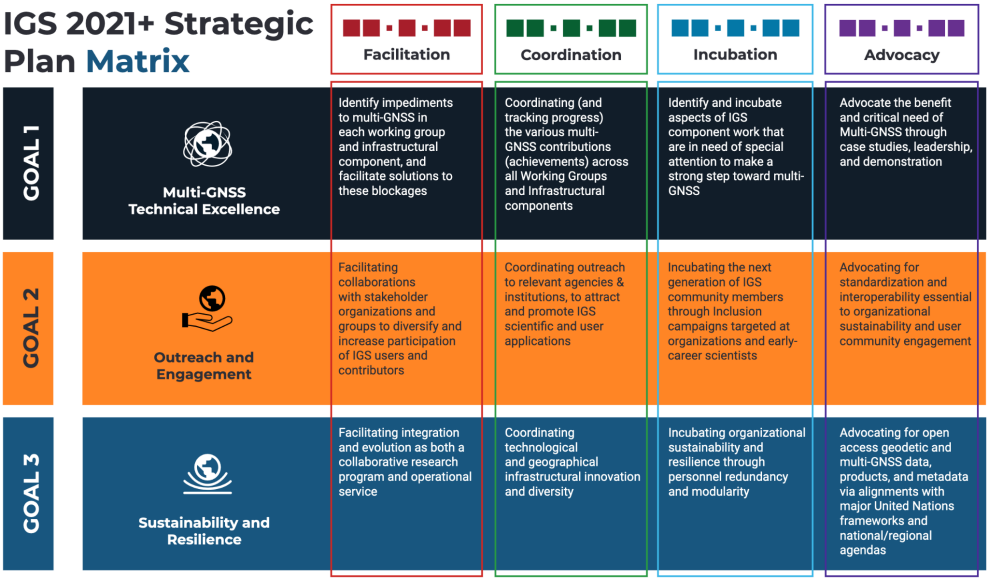

Fig. 2. Matrix summarizing the IGS 2021+ Strategic Plan, available in the Plan's main document at https://igs.org/strategic-planning/

Goal 2 of the Strategic Plan is to strengthen outreach and engagement activities. The IGS seeks to expand the IGS Network and user base through constant outreach endeavors. It maintains a particular focus on underrepresented regions and areas with sparse coverage in order to curate the long-term sustainability of the Service.

Goal 3 is to build a sustainable and resilient organization. In 2021-2023, under the leadership of Ryan Ruddick (Geoscience Australia), a Committee on Sustainable Working Group Governance identified ways in which the IGS Components could be invigorated, in order to ensure they are in the best position to support the IGS in successfully achieving its mission. After delivering its recommendations, the Committee was disbanded in early 2024.

The third goal also aims to develop diverse contributions to the IGS, in order to work towards a well-managed and supported organization with a diverse user base. In pursuit of that objective, a Working Group on Equity, Diversity, and Inclusion

(EDI) was created in 2024, co-led by Elisabetta d'Anastasio (GNS Science Te Pū Ao, New Zealand) and Léo Martire (NASA JPL, USA). It is operational, tasked with the definition objectives to support EDI, and with their ongoing evaluation.

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6 Outreach, Meetings, Publications

Community engagement stands as a cornerstone of the IGS, recognising its voluntary nature and the diverse interests of its stakeholders. In pursuit of this goal, the CB spearheads efforts to foster ongoing dialogue and collaboration among users, experts, and stakeholders worldwide. The CB not only prepares, organizes, and leads numerous meetings annually, but also sustains a steady online presence to consistently be accessible to and approachable by the IGS community.

Introduced in 2021 as both a community outreach and capacity development initiative, the Tour de l'IGS (https://igs.org/tour-de-ligs) is a series of virtual 2-hour-long mini-workshops, each delving into a specific topic of interest. To this day, these events covered issues as broad as reprocessing campaigns, space-borne and ground-based instrumentation, constellation spotlights, or applications to natural hazards. They foster close, frequent, and inclusive engagement within the greater IGS community.

The CB also makes sure to represent the IGS at various large-scale scientific conferences (such as EGU and AGU), as well as gatherings of the IGS' parent/sibling organizations (such as GGOS, various UN bodies, and the IUGG). Notably, the IGS has maintained sessions at AGU every year since 2015, focusing on the value of IGS

products, sometimes in collaboration with GGOS. This consistent presence allows the IGS to regularly broadcast its crucial importance and latest results, while also capturing the attention and interest of a vast spectrum of geodesy and geodesy-adjacent scientists, in an effort to increase robustness and inclusivity within the Service.

IGS Workshops, held every two years since 2004, provide week-long platforms for the IGS community to convene and delve into focused discussions. Due to the COVID-19 pandemic, the 2020 Workshop was held virtually. These gatherings facilitate both open discussions and closed meetings among IGS components, allowing for in-depth exploration of a wide variety of key issues. Recent workshops have seen an increased focus on advancing towards a multi-GNSS IGS.

The CB is responsible for managing the IGS website (https://www.igs.org), which in the last four years has undergone a comprehensive overhaul aimed at improving user experience and enhancing security measures. This revamped website serves as a central online hub for the IGS community, consolidating its digital presence and providing easy access to a wide range of IGS components and products. Notably, the website features the IGS Network Map (see above).

The CB administers mailing lists on specific topics relevant to the global community. The primary mailing list, IGSMAIL, (https://lists.igs.org/mailman/listinfo/igsmail) covers general topics pertinent to the entire IGS community, fostering open communication and collaboration. Using other component-specific mailing lists, members can engage in discussions tailored to their interests and expertise.

The CB maintains an active social media presence. On these platforms, it disseminates important announcements, highlights sessions at conferences, shares new newsletter articles, or communicates other noteworthy updates. This social media engagement is a valuable tool for increasing visibility, fostering community engagement, and promoting the latest developments within the IGS ecosystem.

Since 2021, the CB has extended its outreach efforts through the publication of the IGS Newsletter (https://igs.org/newsletter/), which showcases a diverse range of topics and emphasizes the international nature of the Service. Each edition covers news pertinent to the GNSS community and its stakeholders, along with articles on specific subjects, such as the Hunga Tonga Hunga Ha'apai eruption, the release of ITRF2020, Galileo satellite metadata, or the application of GNSS for disaster risk reduction.

The work performed by the IGS should be acknowledged in scholarly research and other works by citing [4]. Other official publications are the IGS Technical Reports (see https://igs.org/news/igs-technical-report-2023/; similar links for 2022, 2021).

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