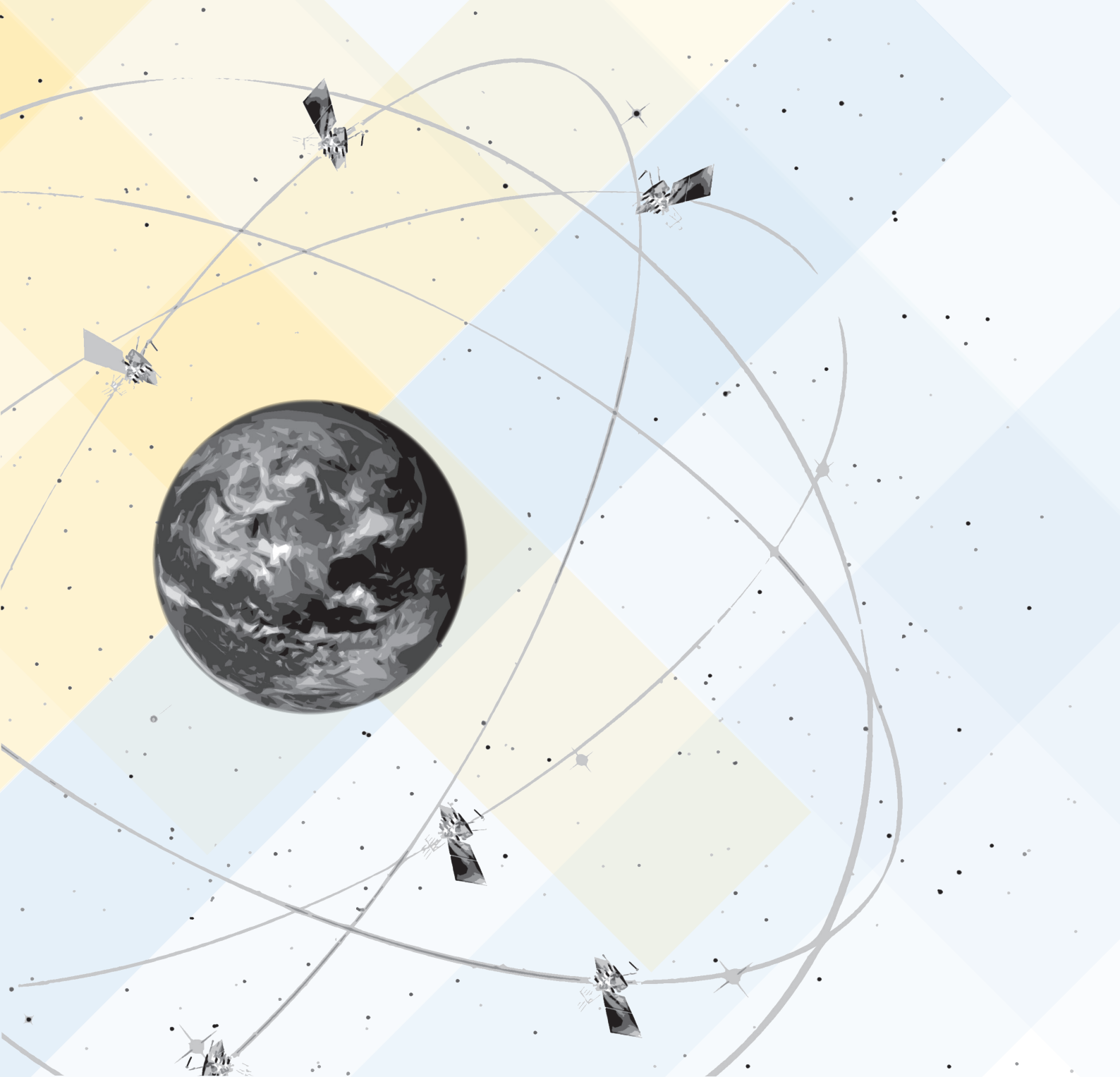
International GNSS Service

IGS

# Strategic Plan

2017



*IGS community members at the 2017 IGS Workshop in Paris, France*
*Photo: IGN/ Xavier della Chiesa*

**Editor**
IGS Central Bureau

**Contact Information**
IGS Central Bureau
Jet Propulsion Laboratory
California Institute of Technology
M/S 238-540
4800 Oak Grove Road
Pasadena, California 91101
United States of America

www.igs.org | cb@igs.org

IGS

The International GNSS Service (IGS) ensures open access, high-quality GNSS data products that enable access to the definitive global reference frame for scientific, educational, and commercial applications.

The IGS is a service of
Global Geodetic Observing System
International Association of Geodesy
International Union of Geodesy and Geophysics

IGS is a Network Member of
International Council for Science - World Data System



ICSU WORLD DATA SYSTEM · IUGG · IAG GGOS Global Geodetic Observing System

# Table of Contents

**4** Executive Summary

**5** Introduction & Mission

**8** Organizational Values

**10** IGS Data & Products

**14** IGS Strategy for 2017 & Beyond

**15** Goals & Objectives

**23** Looking Forward

**Appendices**

**27** Appendix A: Formulation, Implementation & Monitoring of the Strategic Plan

**29** Appendix B: History of the International GNSS Service

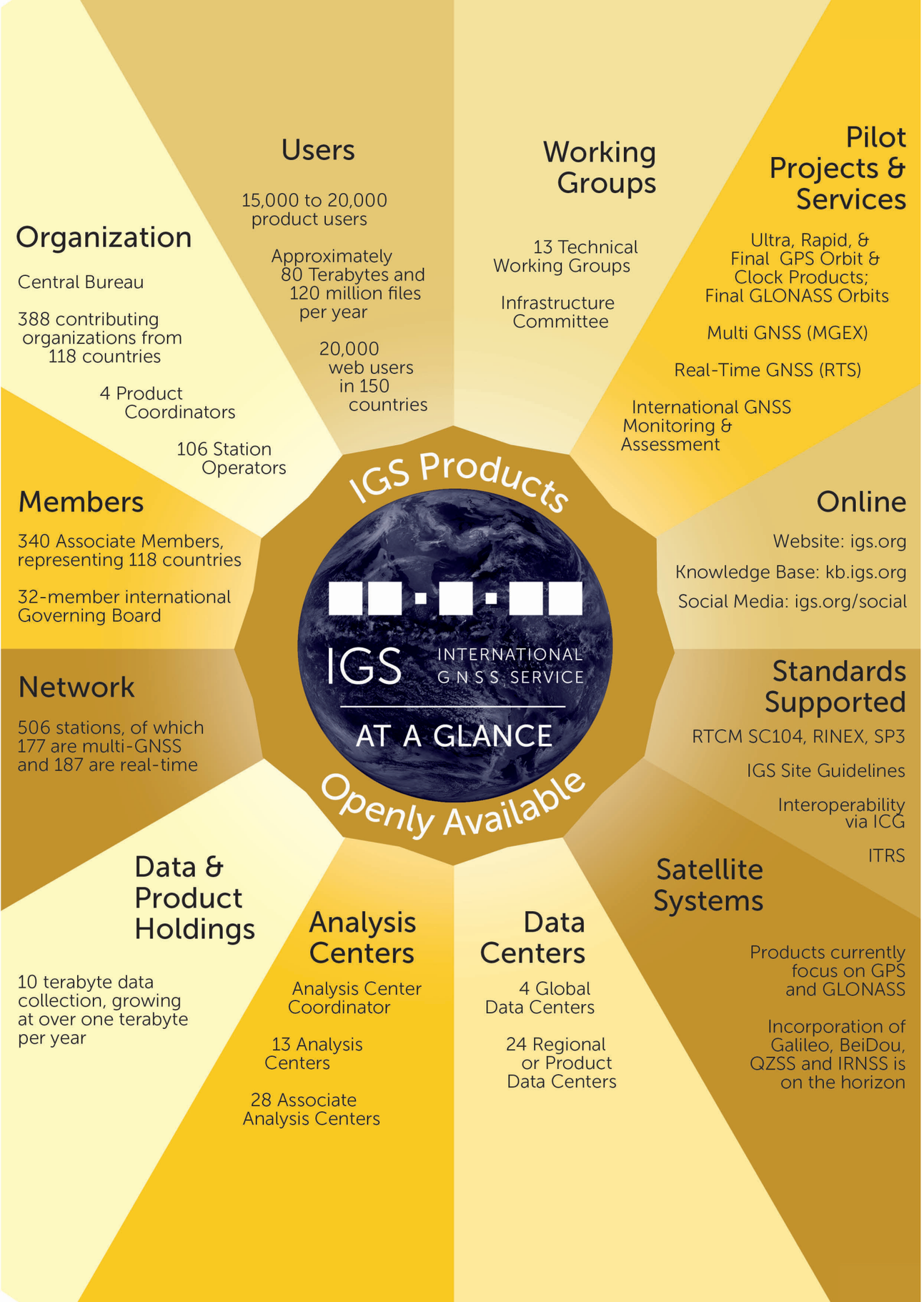
**31** Appendix C: Components & Roles

**37** Appendix D: IGS Governing Board & Membership as of 2017

**39** Appendix E: IGS Organization Structure & Inter-Organizational Relations

**40** Appendix F: Product Availability Standards & Quality of Service

**41** Appendix G: Glossary of Acronyms




# Executive Summary

Dear IGS community and stakeholders,

Welcome to the latest revision of the IGS Strategic Plan. Since the 2013 revision of the strategic plan, the IGS has continued to grow and evolve, all while maintaining its core values and mission.

The IGS continues to coordinate a collaborative research infrastructure at the global scale, not only through the GNSS observing network and data centers, but also through the extensive analysis capability contributed by the participants. The IGS encourages peer reviewed and benchmarked science, not only in the application of IGS data, products and services, but also in the very generation of these outputs. It is in this way that the IGS products continue to be enhanced through time.

The breadth and number of contributors to the IGS, and their high levels of commitment, have however resulted in high levels of performance and reliability of product generation and delivery. It is the combination of this sustained service, high quality data and products, and open data policies that has resulted in the IGS being recognized as the premier source of the highest-quality multi-GNSS related standards and conventions, data and products globally.

The development of this plan has been guided by extensive community consultation. Accordingly, our goals and objectives as documented in this plan which collectively aim to continue the advancement of the IGS in the coming years have been refined to reflect the changing landscape. The Plan is intended to guide our service to the community, and is not intended to be restrictive, therefore allowing the flexibility to ensure the best possible service to the geodetic community.

This plan was developed by the IGS Central Bureau and Governing Board. It does however represent the large cumulative body of work undertaken by the many IGS participants and contributors.

*Gary J*

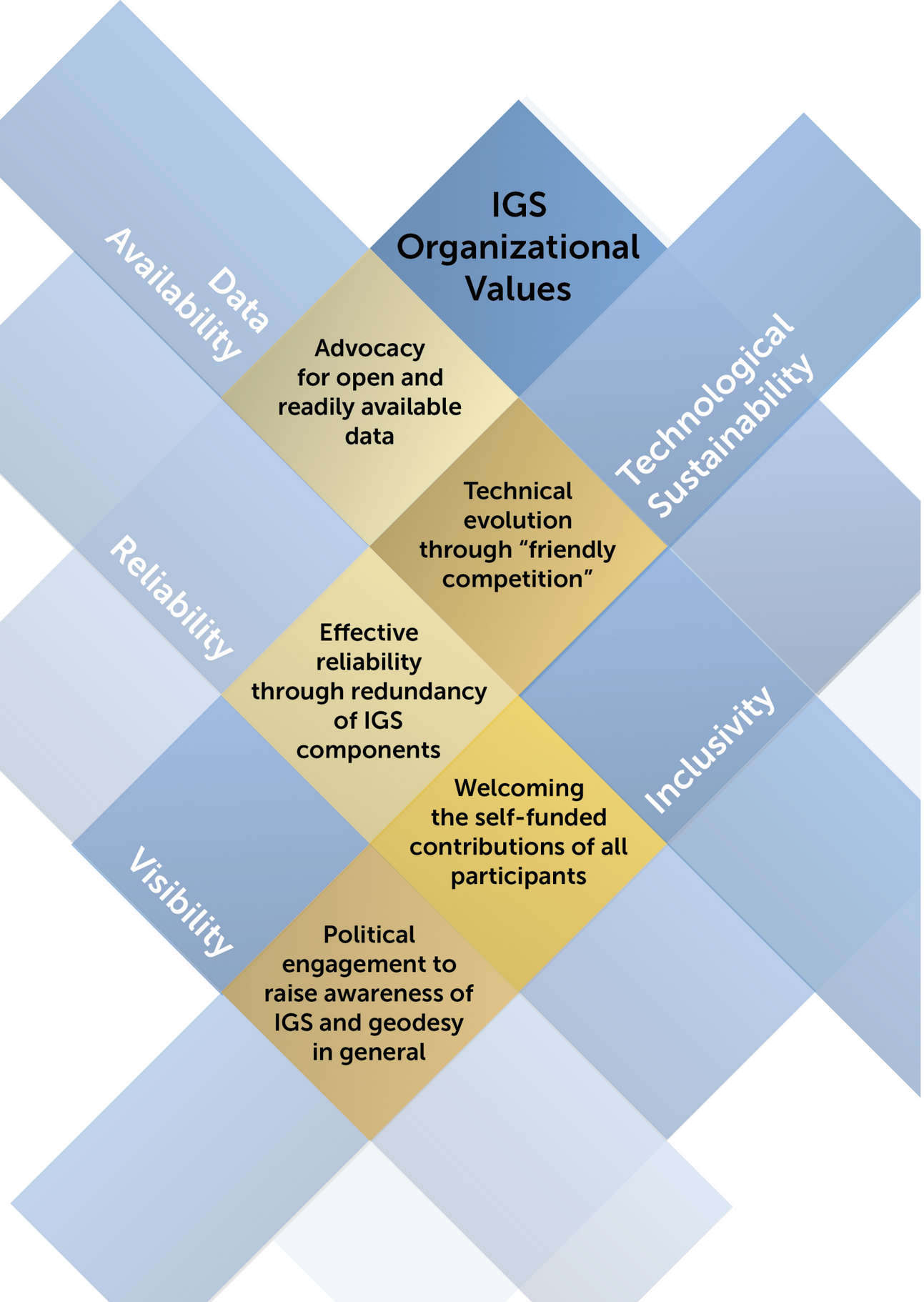
Gary Johnston
Chairman of the IGS Governing Board
Geoscience Australia

# Introduction & Mission

Since its formation as a service of the International Association of Geodesy (IAG) in 1994, the International GNSS Service (IGS) has produced very high quality Global Navigation Satellite System (GNSS) data and products that enable the highest accuracy use of GNSS technologies for scientific and other applications. The IGS data and products are essential for Earth science research; multi-disciplinary positioning, navigation, and timing (PNT) applications; and education.

**Mission**

The International GNSS Service provides, on an openly available basis, the highest-quality GNSS data, products and services in support of the terrestrial reference frame, Earth observation and research; positioning, navigation and timing; and other applications that benefit science, education, and society




# Organizational Values

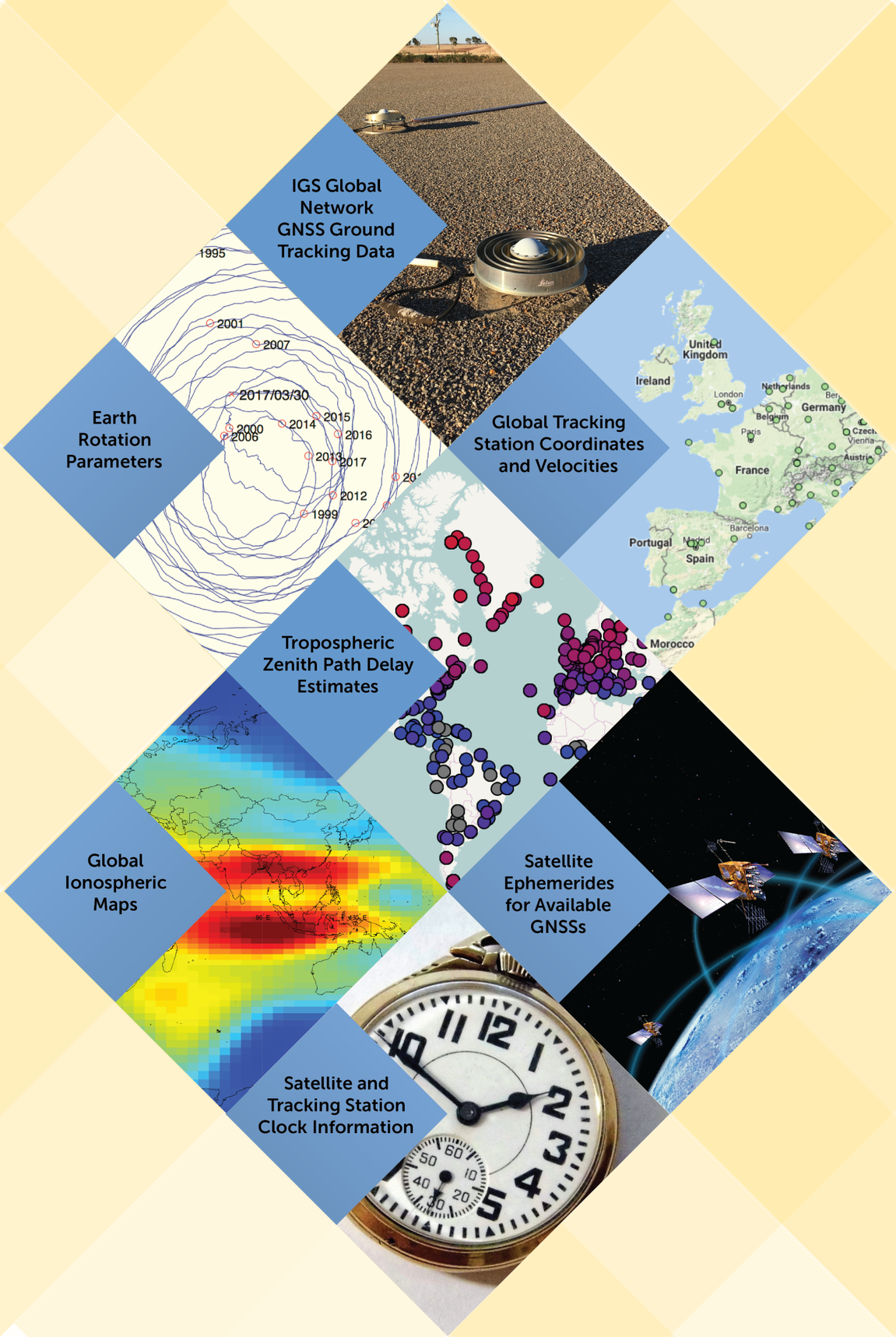
The IGS is organized as a world-wide federation of over 350 participating organizations across 118 countries who voluntarily pool their resources and capabilities to from a cooperative GNSS infrastructure.

Participation within IGS is open to any public or private sector organization with a demonstrated interest in promoting and maintaining the IGS infrastructure and portfolio of GNSS data and products for open public access.

There is no central source of funding for IGS, rather participating organizations self-fund their own contributions. Foundational within IGS is an informal agreement amongst participants to share data and results on a free and open basis, including with the general public.

Fundamental to the IGS are key values that are shared across the organization, namely: advocacy of an open data policy, with data and products readily available; encouragement all organizations, anywhere in the world, to freely participate with self-funded contributions; effective reliability through redundancy of IGS components; technical evolution through "friendly competition;" and dedicated engagement with policy entities to raise mutual awareness of IGS and geodesy in general.

Through this federation, IGS combines multifaceted resources and expertise to enable and advance high precision applications of GNSS. The IGS coordinates a global network of GNSS ground tracking stations, data centers, data analysis centers and technical working groups that provide data and highly refined data products to users around the world.




# IGS Data & Products

IGS data and products include: multi constellation GNSS ground tracking data from IGS global network; precise GNSS satellite orbit solutions for available GNSS constellations; Earth rotation parameters; global tracking station coordinates and velocities; satellite and tracking station clock information; zenith tropospheric path delay estimates; and global ionospheric maps. The IGS products are made available with different latencies, from real-time to weekly.

As a hallmark of IGS, its data and products are made openly available to all users for use without restriction. Data and products offered through IGS are free of cost or obligation, except that users are encouraged to participate within IGS or otherwise contribute to its advancement. Users are asked to acknowledge IGS where the IGS data and products have supported their work.

Although the IGS data and products are offered on a best effort basis, they are redundantly provided through duplicate, independent sources, making them very reliably available to users. The IGS incentivizes self improvement through a process of friendly competition that encourages all participants to continually advance the performance and effectiveness the IGS data and products.

The accuracies of IGS products are sufficient to enable the use of GNSS technologies for scientific applications, such as the improvement and extension of the ITRF, the monitoring of solid Earth deformations, the monitoring of Earth rotation and variations in the liquid Earth (sea level, ice-sheets, etc.), for scientific satellite orbit determinations, precise timing, ionosphere monitoring, and recovery of water vapor measurements.

As a key component of the IAG's Global Geodetic Infrastructure, the IGS contributes to, extends, and densifies the International Terrestrial Reference Frame (ITRF). The ITRF provides an accurate and consistent spatial frame for referencing positions at different times and in different locations around the world. The IGS realization of ITRF, which extends the number of stations significantly, makes the ITRF easily accessible by users around the world.

Technological Sustainability, Visibility, and Inclusivity

**Technical evolution through "friendly competition"**

Positioning of mobile consumer devices and mobile workforce management

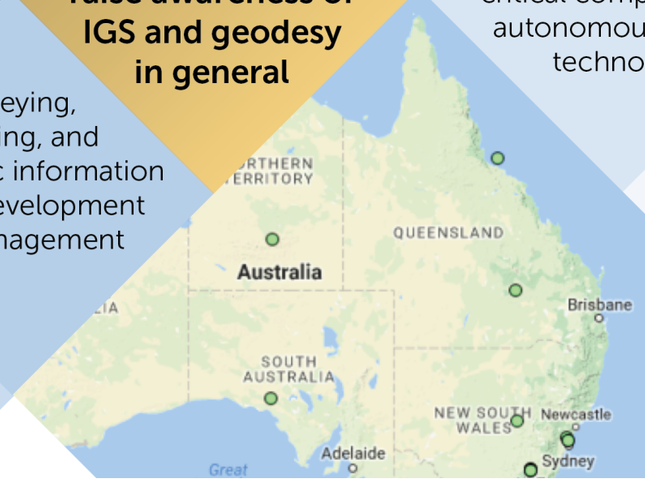
Scientific monitoring, detection, and prediction of natural disasters and other phenomena

Supporting the densification of the ITRF

**Political engagement to raise awareness of IGS and geodesy in general**

Vehicle positioning and navigation; critical components of autonomous vehicle technology

Surveying, mapping, and geographic information system development and management




Although it is driven by a strong rationale to support scientific applications, the IGS contributes to innovation and economic vitality in other areas as well.

The IGS products are considered critical by surveying, geomatics and geo-information users around the world, for example, who rely on them on a daily basis to improve efficiency.



Data Availability and Reliability

**Reliable, open, and readily available data**

Facilitating access to the International Terrestrial Reference Frame (ITRF)

**Global Tracking Station Coordinates and Velocities**

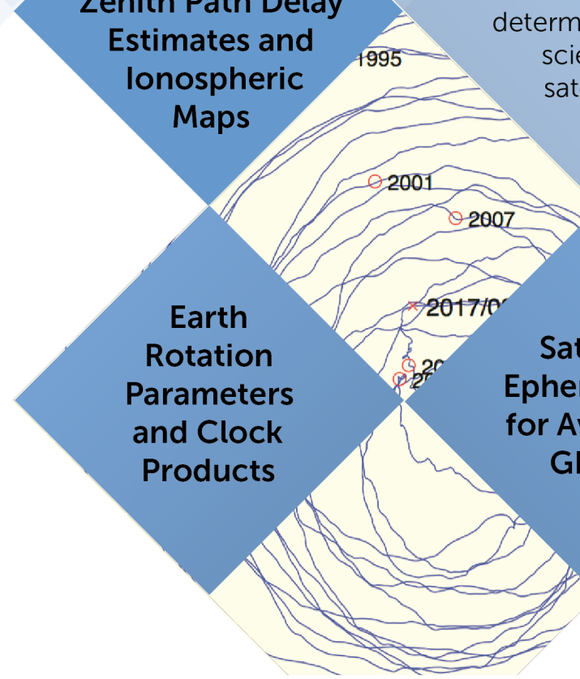
Enabling measurement of the composition and state of the Earth's atmosphere

**IGS Global Network GNSS Ground Tracking Data**

Enabling measurement of length of day, deformation, and rotation of the Earth

**Tropospheric Zenith Path Delay Estimates and Ionospheric Maps**

Supporting Precise Point Positioning for orbit determination of scientific satellites

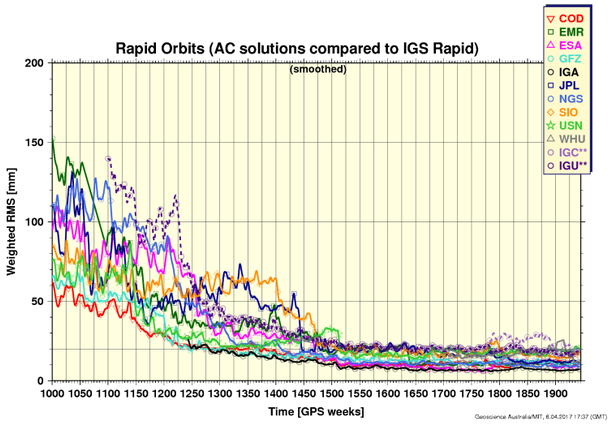


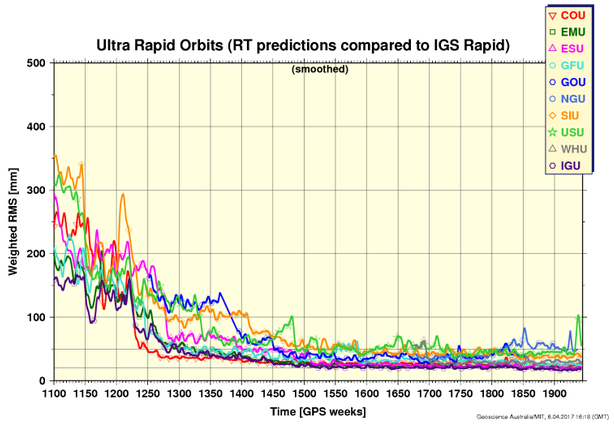

**Earth Rotation Parameters and Clock Products**

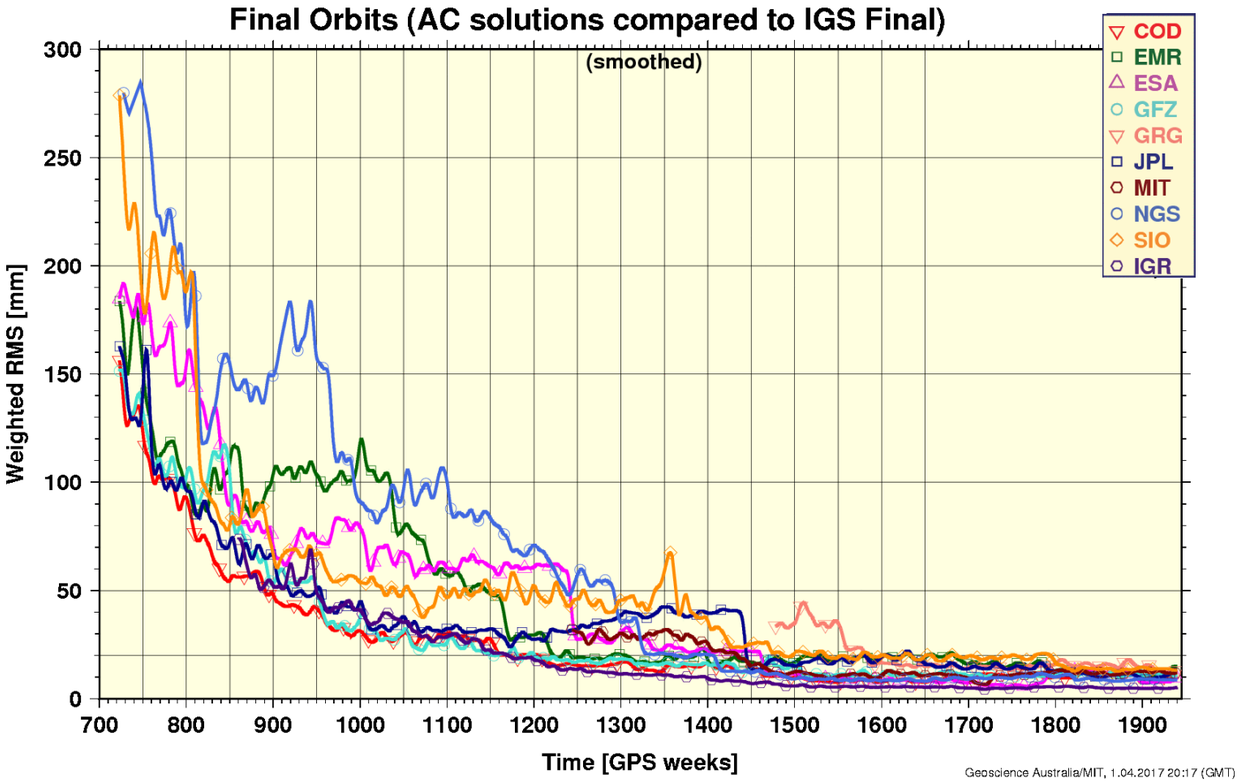
**Satellite Ephemerides for Available GNSSs**

Many applications that require reliable, accurate GNSS positioning in construction, agriculture, mining, exploration, transportation, consumer and other sectors also benefit from the IGS.

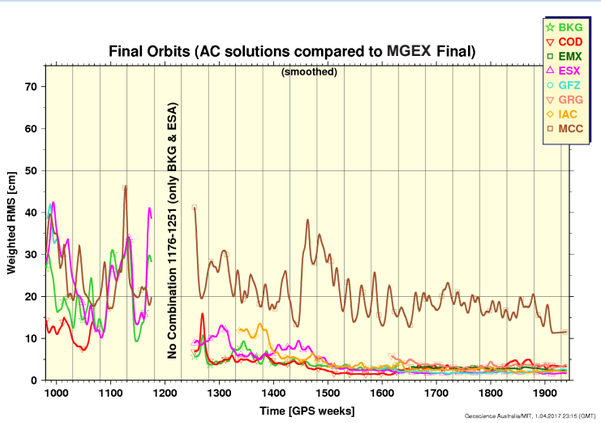
To remain relevant, the IGS must be responsive to these user's needs to effectively evolve its strategy into the future.

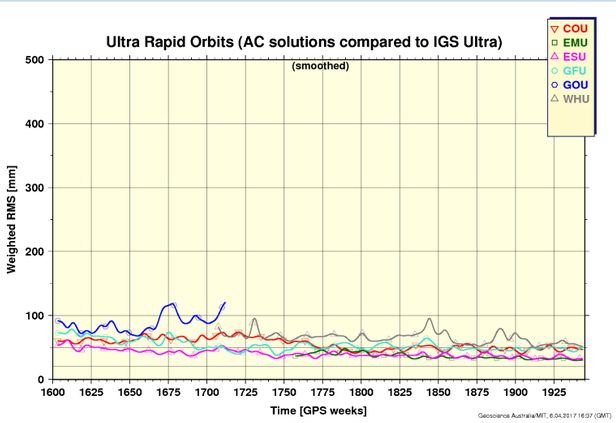



**IGS Product Availability:** goals of world standard, open access, and sustainable GNSS data and products are facilitating unprecedented GNSS accuracy through collaboration, advocacy, and inclusivity.




# IGS Strategy for 2017 & Beyond

As scientific and other GNSS applications proliferate, the work of the IGS and its constituent elements continues to increase in relevance. The importance of the IGS's role has been elevated as applications that essentially rely on the IGS data and products have greatly expanded both within and outside of the sciences.

The IGS Governing Board works in support of continuous improvement of the IGS suite of data and data products, made possible by the efforts of many of dedicated contributors to the IGS.

This Strategic Plan, produced with the assistance of the Central Bureau and many IGS community members, outlines key points of the IGS goals and the anticipated path to meet its objectives in 2017 and beyond. This plan was last reviewed in 2013, aided by community input to a SWOT analysis (strength, weaknesses, opportunities and threats) where IGS stakeholders participated in developing the IGS goals and objectives.

To solicit additional community input to this revision of the plan, Associate Members and IGS stakeholders were asked to complete a strategic planning survey that contained a series of questions related to the strategic direction of IGS. A significant number of responses were received, providing a valuable community view that has been factored into this refinement of the IGS Strategic Plan.

Overall, responses to the planning survey indicated that the goals and objectives set in 2013 remain valid and should be carried forward through the period of 2017 and beyond.

Future undertakings of IGS will be steered by a number of concepts identified through the planning survey. These concepts include:

*High Quality Core Products*
The IGS offers multi-GNSS core products that are benchmarked between IGS Analysis Centers. The IGS prioritizes open data sharing in line with the ICSU World Data Service policies, and achieves a very high level of product availability through federated contributions to product generation and distribution.

*Community Engagement*
Engagement between the IGS Governing Board, Associate Members, users and other stakeholders is desired to strengthen the organization over the long run, as is member awareness and participation in governance.

*Knowledge about Users*
A deeper understanding of IGS users, particularly of potential new users that could affect the direction of IGS, will keep IGS positioned for future opportunities.

*Assessment of Impacts*
Clearly articulating impacts in terms of the IGS's value proposition will help to enhance support for IGS.

*Increase Awareness of IGS*
The IGS must communicate the value of its data, products, and services to potential users, especially those from emerging user sectors who may be less familiar with the IGS products.

These concepts, representing an aggregated view of many thoughtful community members, are considered essential feedback to be appropriately considered with the highest priority in setting the direction of IGS. They will influence positive changes to the IGS activities for the period ahead.

# Goals & Objectives

Generally, the IGS strives to:

- Serve as the premier source of the very high quality multi-GNSS related standards and conventions, data and products, openly available to all user communities
- Attract leading-edge expertise to pursue challenging, innovative projects in a collegial, collaborative and creative culture
- Incorporate and integrate new systems, technologies, applications and changing user needs into IGS products and services
- Facilitate the integration of IGS into the IAG's Global Geodetic Observing System and other broadly based Earth observing and global navigation systems and services
- Maintain an international federation with committed contributions from its members, and with effective leadership, management and governance
- Promote the value and benefits of IGS to society, the broader scientific community, and in particular to policy makers and funding entities

To continue advancing these pursuits, the IGS has refined its strategy for 2017 and beyond. The IGS's actions will be guided by the following framework of three principal goals and derived objectives.

Although the IGS goals have been carried forward unchanged from the 2013 Strategic Plan, some objectives have been reshaped for the coming years in response to contemporary challenges arising from the rapidly expanding landscape of GNSS technology and applications.

# Goal 1

# Openly offer world-standard geodetic products based on GNSS technologies

Goal 1 aims for IGS to remain the premier source for high-quality GNSS data, products, standards, and expertise in the world, with these resources made openly available to all user communities. As a first priority objective, the IGS will continue to support the current core scientific user's needs to sustain a viable global GNSS infrastructure and to reliably produce benchmarked products of the highest quality to advance knowledge of Earth systems. Concurrently, the IGS will strive to evolve with emerging users who have the potential to shape the future direction of the IGS.

The evolution of products to include all GNSS constellations is an ongoing challenge for the IGS. Product enhancements often trigger discussions around the purpose and scope of the IGS, resulting in a review of data and product release policies. At the time of this writing, a review of the policies as they relate to real time multi-GNSS combined products is underway, in anticipation of such a product being available in the future. This review is scheduled for completion in 2018.

**Objective 1.1 – Reliably offer high quality GNSS data and products:** Make every effort to assure that the quality of IGS data and products continues to meet or exceed targeted quality and availability thresholds (Appendix F).

The IGS recognizes that to meet the ongoing changes and challenges associated with Earth-observing activities, it must offer a high-quality service, and enhance service performance whenever possible. To accomplish this, the IGS strives to maintain all components to the highest levels of quality and accuracy; advocates for improvements in IGS infrastructure, network and analysis; and continues to monitor and improve site-related data quality.

This effort supports the overall availability of IGS products, as defined in the Product Availability Standards and Quality of Service matrix (Appendix F), which is monitored as the key performance metric for IGS. The IGS will continue to monitor performance metrics of all components that contribute to product availability, as well as promote friendly competition as a means to advance the IGS products.

**Objective 1.2 – Enhance Services to Meet Evolving User Needs:** Incorporate and integrate new systems, technologies, applications into IGS products and services, ensuring adaptability and robustness to continually meet user needs.

The IGS must continue to optimize its use of technology to increase service performance. New services must be regularly developed to reflect the changing needs of IGS product users, and existing services must evolve to keep pace with demand. For broadest impact, it is essential for all available GNSS signals to be integrated within the IGS portfolio of data and products. Opportunities to apply the IGS products in support of new applications will arise largely from improving interfaces for data access.

Understanding users and their need is critical. The IGS will foster a culture of open innovation that is responsive to continuous feedback and input from users, components, and the community at large. Through this feedback, user requirements, benefits, and future needs will be anticipated and incorporated in improved processes, products, and services. These efforts will also serve as outreach to new user communities as well as build and strengthen partnerships and participation with governmental, educational, and other entities.

**Objective 1.3 – Generate, Improve, and Maintain GNSS Standards**: Establish, evolve and disseminate continuously improving GNSS standards for the purpose of maintaining quality, supportability, and maintainability of IGS GNSS service utilization.

Establishing clear, comprehensive GNSS standards is of utmost importance to the IGS and its users. Standardization of GNSS and its supporting elements will ensure the efficient use of resources for technological development, and provide a key foundational framework for future innovation. Additionally, communicating the value and impact of standards to key decision makers and the overall IGS community will facilitate the steadily increasing integration of standardized GNSS technology in scientific endeavors facing global society.

The IGS will promote standards to encourage open availability of GNSS data and products for societal benefit. It will support the principal organizations involved with GNSS standards to positively influence the development of relevant standards. The IGS will advocate for open access to data and products complying to these standards. In this regard, a key and unique attribute of IGS as a self supported federation is its impartiality and independence of financial influence in developing its products and promoting open standards. Such standards will serve to propagate availability of open GNSS data and products to maximize their benefits and impacts.

# Goal 2

# Advocate for open access geodetic and GNSS data and products

In order to support the advancement of Earth System knowledge, the IGS advocates for openly available GNSS data and products. This enables innovative and cost effective research projects, as well as a variety of other applications to be undertaken. Significant societal benefit arises from the IGS products, and it is in the IGS's interests to communicate these benefits to a wide variety of potential users.

Goal 2 is supported by objectives that seek to maintain or increase personnel expertise to influence GNSS policy and to advocate the value and impact of open access GNSS data and products. It encourages the IGS to engage, communicate and educate where it can positively influence the open access of GNSS and geodetic data products. It supports the development of complementary communications, education and outreach to organizations whose principles and interests may be aligned with those of IGS in promoting open data for public benefit.

**Objective 2.1 – Maintain Expertise:** Maintain and/or increase expertise within IGS to ensure availability and continual advancement of strategic, technical and programmatic capabilities within IGS

The IGS recognizes that global access to expertise is vital to the success of the organization and is committed to attracting talented participants within IGS. Keeping the pipeline of available expertise full requires a deliberate, long term objective that the IGS must continue to pursue with high priority. A multi channel approach will be undertaken by IGS to connect and engage with leading experts in disciplines with interests in advancing the IGS. The outcome of this objective will be a comprehensive network of expertise throughout the IGS community with subject matter experts in the key technical and managerial areas associated with IGS.

**Objective 2.2 – Broaden the IGS Community** through cooperation, integration, and engagement with other Earth-observation and geoscience organizations

The efficient and ongoing integration of IGS products and services into existing global Earth-observing and navigation systems is of great mutual importance to the IGS and its diverse pool of collaborators.

Actively seeking out new avenues for engagement and cooperation with Earth scientific organizations will broaden the IGS user community, and ultimately produce a finely networked web of product and organizational integration within and around the IGS. This will ensure the optimal use of organizational and technological resources, and broaden the general user community while integrating it internally.

The IGS will continue to participate in the IAG's Global Geodetic Observing System, the Group on Earth Observations (GEO), and the committee on Earth Observation Satellites (CEOS). As part of its obligation as a service of the IAG, the IGS will continue to participate in relevant United Nations committees, such as the Committee of Experts on Global Geospatial Information Management and the International Committee on GNSS. By working with these organizations, the IGS seeks to build a broader global awareness and participation with nations and regions not currently active within the Service.

**Objective 2.3 – Facilitate Community Information and Expertise Sharing:** Provide a central forum for community experts to discuss and explain various aspects of GNSS and geodesy for the benefit of all interested – from experts to students.

Leveraging on its network of experts, the IGS will continue to engage as a community through a number of channels. Principally, the IGS workshops, held on a rotating basis by different IGS participants on an 12-18 month interval, are a principal avenue for connecting the entire IGS community of participants, users and stakeholders.

Technical workshops involving subject matter experts addressing highly specialized topics are held more frequently, as are interactions within the IGS working groups and Projects. To promote awareness and transparency within IGS, the IGS Governing Board, Associate Members and other interested parties engage in an annual open meeting, which was successfully initiated in 2016.

The IGS will also expand its engagement to reach an even broader audience through online channels. The IGS website continues to be enriched with an abundance of content and information, especially igs.org/presents. The IGS community of experts will be encouraged to contribute knowledge and information through the IGS website for access by the entire community as well as the general public. Similar avenues for interaction will be introduced at IGS Workshops, including clinics for the latest technology, special plenary presentations, and other designated events for discussion and education across areas of interest.

**Objective 2.4 – Maintain or Increase Policy Advocacy:** Maintain and increase IGS presence in policy-making entities.

The purpose of this objective is to enhance the policy outreach and education activities of the IGS, ranging from workshop attendance to active advocacy initiatives. Policy advocacy is critical to the ongoing success of the IGS. Numerous initiatives have been positively influenced by the IGS, and many more continue to, or will in the future, benefit from IGS affiliation or involvement.

By participating on the United Nations Committee of Experts on Global Geospatial Information Management, Working Group on Global Geodetic Reference Frame (GGRF), the IGS is a key advocate of policy for countries around the world to cooperate in extend the GGRF as a basis for mapping and geodetic measurement.

# Goal 2 (continued)

## Advocate for open access geodetic and GNSS data and products

The IGS is also active through its role as an IAG service with the United Nations International Committee on GNSS, which coordinates between the GNSS providers on important policy matters relating to interoperability and performance of the various GNSSs. The IGS is a key committee member that advises ICG on scientific and policy matters. These and other efforts benefit from the broad advocacy efforts in which the IGS participates.

**Objective 2.5 – Increase Communications and Outreach Efforts**: Strong, succinct, and diverse communications efforts will be implemented to educate the geodetic community, community stakeholders, and the general public.

Communications is essential to support the work of the IGS both financially and politically, as well as to ensure the education and engagement of the next generation and a sustainable future for the IGS Mission. The development of high-quality communications will assist members and contributing organizations to build stronger relationships with decision-making authorities as well as supplementing their own public relations resources.

# Goal 3

## Ensure an effective and sustainable organization that can be relied upon over the long-term

Goal 3 calls for IGS to vigilantly maintain effective governance and support to sustain itself as a long-term enterprise. Objectives relate to strengthening governance and related practices, as well as strengthening the IGS funding base. The desired outcome is a well managed and supported organization with a diverse user base, and a well defined vision and means for the future.

**Objective 3.1 – Strengthen Governance:** IGS will continue to incorporate best practices to maintain and improve its organizational efficiency.

Effective governance is a key element in the success of the IGS. In order to ensure that all segments of the organization are achieving desired results, the IGS will continually self-audit by monitoring a dashboard of metrics, designed to assess health and effectiveness, and use this information to steer performance. The outcome of this objective will be to increase the maturity of processes and practices across the organization to effectively strengthen governance.

**Objective 3.2 – Maintain Funding to Sustain IGS:** IGS will centralize the efforts of its self-funded participants to strengthen support for the IGS activities and communicate the value of IGS to a broader sector of its community.

This objective seeks to support the IGS self-funded participant model, as well as to increase contributions to IGS through diverse sources. By helping the IGS participants to succinctly articulate the IGS value proposition, the IGS may positively impact participant funding over the long term. Sponsors must be convinced that by supporting the IGS, their investments are leveraged multifold by the benefits of IGS participation. Growth may be realized as new opportunities are pursued that may lead to more diverse participation within IGS.

By developing a better understanding of its users and impacts, the IGS can help its participants justify their involvement, and hence funding for IGS. The overall output of this objective will be a stable organization of diverse participants who are stably funded over the long term to support IGS activities.

# Looking Forward

This Strategic Plan provides a clear direction for advancing IGS in 2017 and beyond. The IGS will remain committed to providing its world standard products to diverse users working on innovative applications.

The IGS will continue to build a sustainable organization that pushes the limits of technology to improve the overall effectiveness of the organization. We envision that, guided by this plan, IGS will emerge and continue to be an organization that is well positioned to take on its next set of challenges in the years ahead.

# Appendices

Appendix A: Formulation, Implementation & Monitoring of the Strategic Plan

Appendix B: History of the International GNSS Service

Appendix C: Components and Roles

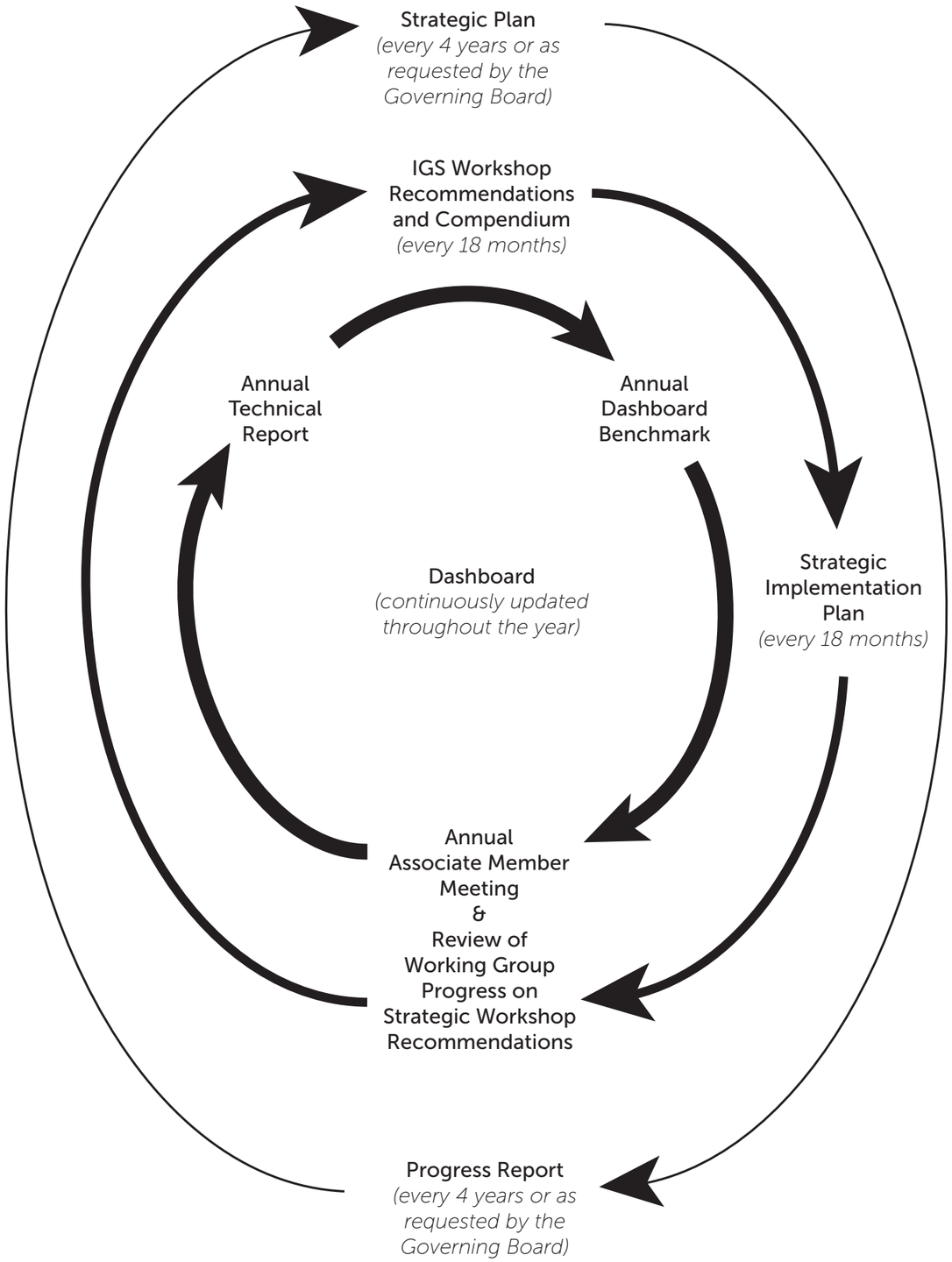
Appendix D: IGS Governing Board and Membership as of 2017

Appendix E: IGS Organization Structure and Inter-Organizational Relations

Appendix F: Product Availability Standards and Quality of Service

Appendix G: Glossary of Acronyms

Strategic Planning Community Survey Summaries are available for viewing and download in the Publications section of the IGS Knowledge Base:
http://kb.igs.org
http://bit.ly/IGS-SP15-Survey






# Appendix A

## Formulation, Implementation & Monitoring of the Strategic Plan

This Strategic Plan is intended as a living document that may be revised or updated whenever the IGS Governing Board (GB) deems it to be necessary, typically every four to five years.

To initiate a reformulation of the plan, the GB will appoint a Strategic Planning Committee (SPC), which will be co-chaired by the Director of the IGS Central Bureau and the Chair of the Governing Board. The SPC members will include all of the Executive Committee members, as well as any other Governing Board Members and Associate Members who volunteer to participate. This committee is tasked and authorized, through the GB and with the support of the Central Bureau, to formulate the strategic plan.

Input from IGS stakeholders is a key aspect to be considered in the formulation of the IGS strategy. Input may be sought by various means, such as SWOT analysis (Strength/Weakness/Opportunity/Threat), stakeholder surveys, organized meetings, or by any other method deemed appropriate by the SPC in the process of formulating IGS strategy.

Following a period of public review, where the IGS Associate Members and others are invited to provide comments, the reformulated Strategic Plan is to be approved by the Governing Board.

The principal deliverable of the IGS workshops are succinct lists of recommendations for advancing the IGS. These recommendations cover all aspects of the IGS and are submitted to the GB for consideration. The GB's job is then to assure that these recommendations reflect and support the IGS strategy. Once adopted, these recommendations form a roadmap to implement and advance the IGS strategy on a nominal 18-month cycle. IGS activities are constructed to achieve these recommendations. The core of the strategic plan implementation is to identify, assign, execute, and monitor the progress of these activities, which can be multi-year efforts depending on their nature.

The IGS must succeed in key areas in order to achieve its goals and carry out its mission. To measure its success, the IGS monitors a set of metrics designed to evaluate effectiveness in achieving defined objectives. These include metrics related to the health of the organization and governance, quality of products, data holdings, access and users, which are actively updated through the IGS website. The metrics provide an ongoing dashboard view of the general health of the IGS and can be used by the GB to steer the progress of IGS.

The GB will regularly interact with the IGS Associate Members to seek input on the IGS strategy and any aspect of the IGS activities. Performance of all of the IGS components is reviewed annually during Governing Board Meetings.

Detailed progress on the IGS activities is documented annually through the IGS Technical Report. In addition, on an approximate 4-5 year schedule, coincident with reformulations of the Strategic Plan, IGS progress will be summarized in a Progress Report. This report will be comprised principally of a tabulation of metrics tracked in monitoring IGS progress.

# Appendix B

## History of the International GNSS Service

Since the late 1980s, the U.S. Global Positioning System (GPS) constellation of satellites has come to play a major role in regional and global studies of Earth. In the face of continued growth and diversification of GPS applications, the worldwide scientific community has made an effort to promote international standards for GPS data acquisition and analysis, and to deploy and operate a common, comprehensive global tracking system.

The International GNSS Service (IGS) was established in January 1994 as a service of the International Association of Geodesy (IAG), and was originally named the International GPS Service for Geodynamics. In 1999, the name was shortened to International GPS Service, as the applications of GPS within the scientific community were extending well beyond geodynamics. The current name of the IGS – International GNSS Service – was officially adopted in 2005 to reflect IGS' intent to integrate not only the United States Global Positioning System (GPS), but also the significant contributions of other GNSS, such as the Russian GLONASS, European Galileo, Chinese BeiDou, and Japan's QZSS.

As the then-new GPS began to be used for research and science applications, many organizations recognized the enormous potential of the unprecedented level of positioning achievable with this technology, at relatively economical cost. In light of this, it was decided that no single entity could, or should, assume the capital investment and recurring operations costs for such a global system. It was at this point that key international players first considered joint partnerships to define international cooperative efforts and to set standards that would ensure the success of this endeavor and its ultimate goal of promoting high quality scientific achievements. By the late 1980s, many geodynamic and geodetic organizations recognized the potential of GPS, and at the 1989 International Association of Geodesy (IAG) Scientific Assembly meeting in Edinburgh, Scotland, it was recognized that a standardized civilian system for using GPS would be beneficial to all.

In 1991, a Call for Participation was organized by the IAG Planning Committee seeking participants and contributors who would develop a "proof of concept" of an international service. It requested interested groups to assume the role of station operations, networks, data centers, analysis centers, and a Central Bureau for coordination of the activity. Following a large, positive response, the International GPS Service Oversight Committee was formed at the International Union of Geodesy and Geophysics (IUGG)/IAG General Assembly meeting in Vienna in 1991.

The Committee organized a successful pilot project in 1992 to demonstrate the potential of an international service based on GPS. The IGS was determined to be clearly viable, and its pilot project continued without interruption through 1993, while a proposal was prepared to the IAG seeking approval for the IGS as an IAG international service. Approval was received at the IAG Scientific Assembly in Beijing in 1993, and the IGS was officially established on January 1, 1994. Two years later, the IGS was granted membership in an inter-disciplinary body of International Council of Science (ICSU): the Federation of Astronomical and Geophysical Data Services (FAGS).

The IGS operates its global civilian GPS tracking system for science and research on a completely voluntary basis. Since the pilot project in 1992, the network has grown from approximately 30 permanent GPS stations to more than 400; and the 3-D WRMS accuracy of the IGS orbits has improved by more than an order of magnitude, from 50 cm to better than 3 cm.



The IGS continues developing and improving traditional products such as orbits, clocks, station positions and velocities, Earth rotation parameters (ERP), as well as fostering projects and working groups that produce additional data products, such as wet troposphere zenith path delays (ZPD) and total electron content (TEC). These IGS projects and working groups are dependent upon the infrastructure of the IGS for scientific applications.

Projects that have been completed and are now incorporated into IGS routine processes include the Precise Time and Frequency Project — jointly with the Bureau International des Poids et Mesures (BIPM) — the International GLONASS Pilot Project (IGLOS PP), and the Tide Gauge Project (TIGA).It is the infrastructure of the IGS and innovative efforts of the IGS Analysis Centers that have driven the evolution and improvements of the IGS that, in turn, support these science-driven applications.

Through its Analysis Centers and Working Groups, the IGS continues to evolve and improve. The IGS has become the primary source for general access to, and continuous development of, the precise reference frame of the International Earth Rotation and Reference Systems Service (IERS): the International Terrestrial Reference Frame (ITRF). This is particularly due to the dense distribution of this geodetic technique and the economies of use.

The IGS provides the global framework for virtually all regional applications and networks, including:

- The United States Plate Boundary Observatory GPS Network (PBO), managed by a key IGS partner, the University NAVSTAR Consortium (UNAVCO)
- IAG Commission 1 Reference Frames, which includes the
- Subcommission for Europe (EUREF);
- Sistema de Referencia Geocéntrico para América del Sur (SIRGAS, the South American continental reference system);
- Unification of African Reference Frames (AFREF);

and others.

The history, development, and current status of the IGS are captured online, particularly in workshop proceedings and their archives. All are maintained and available through the Central Bureau website, http://igs.org/.

And historically the IGS Annual Reports, Technical Reports, and Strategic Plans, noting the great success of the Astronomical Institute of the University of Bern, which assumed the responsibility for the IGS Technical Reports in 2012.

Since 2012, several major activities have been developed in the areas of multi-GNSS and real-time GNSS. The IGS multi-GNSS network is now capable of including all observed GNSSs, including the capacity for multi-GNSS clocks. The IGS Real Time Service launched on April 1, 2013 and currently includes GPS and experimental GLONASS real-time orbit and clock products.

There has also been the development of a GNSS Performance Monitoring IGMA-IGS Joint Trial Project, as a joint activity of GNSS Providers and the IGS. The Trial Project is organized through the International GNSS Monitoring and Assessment Task Force of the United Nations Office of Outer Space Affairs, International Committee on GNSS (UNOOSA-ICG). The Project seeks to create an authoritative international GNSS monitoring and assessment system to benchmark the performance of available GNSSs.

# Appendix C

## Components & Roles

### Global Network of Tracking Stations

At the heart of the IGS is a network of hundreds of GNSS tracking stations that are operated by participating agencies from around the world. For an up-to-date list of the IGS tracking stations and station operators, please refer to the IGS website at http://www.igs.org/network.

All components of the IGS are critically dependent on the global network of precise GNSS tracking stations. The IGS network includes over 500 stations, 177 of which are multi-GNSS, that operate continuously, delivering data in real-time, near real-time, high rate, hourly or daily to data centers. A subset of the network, comprising 189 stations, provides real-time data streams within the IGS Real-Time Service. The IGS network today also includes 196 GLONASS tracking stations.

The operation of the IGS Network is conducted by 388 different organizations around the world, of which over 200 are actively involved. Daily business and support is coordinated by the Central Bureau to assure that consistent, organized, and high-quality data are provided to the Analysis Centers (ACs) and other users.

### Data Centers

Since the inception of the IGS, archives of its Data Centers (DCs) have become increasingly important to a wide range of scientific and research applications. The distributed nature of the data flow supporting the IGS has been key to the successful archiving and availability of both IGS data and products. A hierarchy of DCs distributes data from the network of tracking stations; the Operational, Regional, and Global Data Centers.

This scheme provides efficient access and storage of GPS and ancillary data, thus reducing network traffic as well as providing a level of redundancy allowing for security of the data holdings. There are six Global DCs, seven Regional DCs, 17 Operational DCs, and one Project DC.

#### Global Data Centers

| Institution | Abbreviation | Country |
|---|---|---|
| Institut Geographique National | IGN | France |
| Korean Astronomy and Space Science Institute | KASI | Korea |
| Crustal Dynamics Data Information System | CDDIS | USA |
| Scripps Institution of Oceanography | SIO | USA |
| Wuhan University | WHU | China |
| European Space Agency / ESAC | ESA / ESAC | Spain |

#### Regional Data Centers

| Institution | Abbreviation | Country |
|---|---|---|
| Geoscience Australia | GA | Australia |
| Wuhan University | WHU | China |
| Bundesamt für Kartographie und Geodäsie | BKG | Germany |
| RDAAC-IRIS | RDAAC-IRIS | Russia |
| Hartebeesthoek Radio Astronomy Observatory | HRAO | South Africia |
| NGS/NOAA Operational Data Center | NGS/NOAA | USA |
| Jet Propulsion Laboratory | JPL | USA |

#### Operational Data Center

| Institution | Abbreviation | Country |
|---|---|---|
| Geoscience Australia (formerly AUSLIG) | GA | Australia |
| Geological Survey of Canada | PGC | Canada |
| Geodetic Survey of Canada | NRCAN | Canada |
| Kort & Matrikelstyrelsen/National Survey & Cadastre | KMS | Denmark |
| Centre National d'Etudes Spatiales | CNES | France |
| European Space Agency/ESOC | ESA/ESOC | Germany |
| GeoForschungsZentrum | GFZ | Germany |
| Hartebeesthoek Radio Astronomy Observatory | HRAO | Italy |
| Italian Space Agency | ASI | Italy |
| Geographical Survey Institute | GSI | Japan |
| Delft University of Technology | DUT | Netherlands |
| Norwegian Mapping Authority | SK | Norway |
| RDAAC-IRIS | RDAAC-IRIS | Russia |
| Jet Propulsion Laboratory | JPL | USA |
| NGS/NOAA Operational Data Center | NGS/NOAA | USA |
| Scripps Orbit and Permanent Array Center | SOPAC | USA |

#### Project Data Center

| Institution | Abbreviation | Country |
|---|---|---|
| Universite de La Rochelle > Tide Gauges & GPS | TIGA | France |

## Analysis Centers and Associate Analysis Centers

The ACs form the operational and scientific backbone responsible for generating the IGS products. They provide, based on the available tracking data of the whole IGS network, a consistent set of high-quality products such as precise satellite orbits, station and satellite clock information, station coordinates, Earth rotation parameters, and atmospheric information.

To fulfill the tasks of an IGS AC, all products have to meet the highest standards according to IGS and IERS conventions and standards, and all submissions must be published in a timely and regular manner. Currently, the IGS ACs offer three types of solutions, which differ in accuracy and latency, to many kinds of scientific and engineering applications, specifically: ultra-rapid sub-daily products, daily rapid products, and weekly final products.

Besides their routine work, the ACs continually strive to improve the model, crucial to the success of the IGS. There are currently 13 ACs that work with the Analysis Center Coordinator, distributed across two centers, Geoscience Australia and the Massachusetts Institute of Technology, in two continents hemispheres apart, using combination software operating on Cloud computing services (Amazon Web Services).

Associate Analysis Centers are organizations that produce specialized products, such as ionospheric information or station coordinates and velocities for a global or regional sub-network. These ACs are generally linked to a corresponding IGS Pilot Project or Working Group. Currently, there are 28 of these Associate Analysis Centers.

### Analysis Center Coordinator

The IGS Analysis Center Coordinator (ACC) has overall responsibility for generating the official IGS combined products. Specifically, the ACC assures quality control of the IGS products, evaluates performance, develops analysis standards, and assembles the outputs from all Analysis Centers into a single set of official IGS products. Responsibility for producing the IGS combined products officially transitioned from NOAA/NGS to Geoscience Australia on 1st January 2016, and is managed jointly by GA and MIT.

**Analysis Center Coordinator (ACC)**

| Institution | Abbreviation | Country |
|---|---|---|
| Geoscience Australia & Massachusetts Institute of Technology | GA/MIT | Australia/USA |

**IGS Analysis Centers (ACs)**

| Institution | Abbreviation | Country |
|---|---|---|
| Natural Resources Canada | EMR | Canada |
| Wuhan University | WHU | China |
| Geodetic Observatory Pecny | GOP-RIGTC | Czech Republic |
| Space geodesy team of the CNES | GRG | France |
| European Space Agency/ESOC | ESA/ESOC | Germany |
| GeoForschungsZentrum | GFZ | Germany |
| Center for Orbit Determination in Europe | CODE | Switzerland |
| Jet Propulsion Laboratory | JPL | USA |
| Massachusetts Institute of Technology | MIT | USA |
| NOAA/National Geodetic Survey | NGS | USA |
| Scripps Institution of Oceanography | SIO | USA |
| U.S. Naval Observatory | USNO | USA |

**Associate Analysis Centers (ACs)**

**Global Network Associate Analysis Centers (GNAACs)**

| Institution | Country |
|---|---|
| Chinese Academy of Sciences, Institute of Geology and Geophysics | China |
| University of Newcastle-upon-Tyne | UK |
| Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology | USA |

**Regional Network Associate Analysis Centers (RNAACs)**

| Institution | Country/Region |
|---|---|
| Geoscience Australia (GA), Space Geodesy Analysis Centre | Australia |
| EUREF - IAG Commission X - Global and Regional Geodetic Networks, Subcommission for Europe (European Coordinating RNAAC): | Europe |
| Bundesamt für Landestopografie (swisstopo) | Switzerland |
| Center for Orbit Determination in Europe | Switzerland |
| Geodetic Observatory Pecny (GOP-RIGTC) | Czech Republic |
| Bundesamt für Kartographie und Geodäsie (BKG) | Germany |
| International Commission for Global Geodesy of the Bavarian Academy of Sciences | Germany |
| Nordic Geodetic Commision | Finland |
| Nuova Telespazio S.p.A., Space Geodesy Center | Italy |
| Lustbühel Observatory, Graz | Austria |
| Royal Observatory of Belgium | Belgium |
| University of Padova | Italy |
| Warsaw University of Technology | Poland |
| Geographical Survey Institute of Japan | Japan |
| Geophysical Institute of the University of Alaska | USA |
| Onsala Space Observatory | Sweden |
| Pacific Geoscience Center | Canada |
| SIRGAS - Sistema de Referencia Geocentrico para las Americas, the South American Geocentric Reference System - Deutsches Geodätisches Forschungsinstitut | South America |

**Working Groups and Pilot Projects**
The work of supporting and developing the IGS components is carried out by Working Groups that may be tasked with the execution of various Pilot Projects or experiments. Working Groups focus on selected topics related to the IGS com¬ponents, according to goals and schedules specified in the working group's charter. Pilot Projects or demonstration experiments aim to develop particular IGS products or services that rely on the IGS infrastructure.

At present, the IGS Working Groups are:
- Antenna Working Group
- Bias and Calibration Working Group
- Clock Products Working Group
- Data Center Working Group
- Monitoring and Assessment Working Group
- Multi-GNSS Working Group
- Ionosphere Working Group
- Real-Time Working Group
- Reference Frame Working Group
- RINEX Working Group
- Space Vehicle Orbit Dynamics Working Group
- Tide Gauge (TIGA) Working Group
- Troposphere Working Group

Current IGS Pilot Projects:
- GNSS Performance Monitoring IGMA-IGS Joint Pilot Project
- Real-Time Pilot Project
- Multi-GNSS Extension (MGEX)

Former Working Group:
- Low Earth Orbiters (LEO)

Previous Pilot Projects, which were concluded successfully and integrated into the mainstream IGS activities, were:

- Precise Time and Frequency Project, jointly with the Bureau International des Poids et Mesures (BIPM), is now the IGS Clock Products Working Group with a specific coordinator located at Naval Research Laboratory
- International GLONASS Service Pilot Project (IGLOS-PP) which is now fully integrated into IGS processing, and hence the catalyst for renaming IGS as the "GNSS" service
- Tide Gauge (TIGA), now actively providing links from tide gauges to the IGS network as a method for contributing to measuring sea-level change

**IGS Governing Board**
The principal role of the Governing Board (GB) is to set policy and to exercise broad oversight of all IGS functions and components. It also controls IGS efforts to maintain efficiency and reliability. A complete list of Governing Board, former Governing Board, and Associate Members may be found in Appendix D.

**Central Bureau**
The Central Bureau (CB) is the executive arm of the IGS and is responsible for the general management and coordination of IGS activities and external affairs consistent with the directives, policies, and priorities set forth by the GB. The CB coordinates with IGS tracking station operators to assure consistent delivery of high-quality standardized data to Analysis Centers. Additionally, the CB facilitates critical assessments of infrastructure components through the IGS Infrastructure Committee, which is tasked with making recommendations to the GB to improve the overall service. The CB is also the primary outreach organization for communication and coordination of the IGS activities with broader GNSS initiatives around the world. The Central Bureau Information System (CBIS) is the main information portal for all of the IGS components and is also operated by the CB.

**The IGS Institute**
The IGS Institute serves as a nonprofit US legal entity (501.C3 US Corporation) established to complement the IGS GB and CB. The IGS Institute can conduct business with international organizations, industry, and the general public on behalf of the IGS and its many components. It was established as a nonprofit public benefit corporation in September 2008. The IGS Institute, Inc., is located in California and is structured to conduct business as needed for the IGS.



**Supporting Organizations**
At the heart of the IGS are its supporting organizations, whose ongoing support sustains the IGS and its work. Organizations hosting Data and Analysis Centers were already introduced earlier in this appendix; additional contributors, and their component support roles, are detailed below:

Reference Frame Coordinator
Institut National de l'Information Géographique et Forestière, France

Clock Products Coordinator
US Naval Research Laboratory, USA

Infrastructure, Operations, and Network Coordinator
IGS Central Bureau,
NASA Jet Propulsion Laboratory,
California Institute of Technology, USA

Central Bureau
NASA Jet Propulsion Laboratory,
California Institute of Technology, USA

Pilot Projects and Services
- Real-Time Service, Bundesamt für Kartographie und Geodäsie and ESA European Space Operations Centre, Germany
- IGMA Joint Performance Monitoring, ESA European Space Operations Centre, Germany

Former Pilot Projects
- International GLONASS Service Pilot Project (IGLOS-PP), National Geospatial-Intelligence Agency, USA
- Precise Time and Frequency Project, US Naval Research Laboratory, USA; and Bureau International des Poids et Mesures, France
- Tide Gauge Benchmark Monitoring (TIGA), Deutsches GeoForschungsZentrum, Potsdam, Germany

Working Groups and the Institutions or Organizations of their Current Chairpersons
- Antenna WG, Deutsches Geodätisches Forschungsinstitut, Germany
- Bias and Calibration WG, Astronomical Institute, University of Bern, Switzerland
- Clock Products WG, US Naval Research Laboratory, USA
- Data Center WG, NASA Goddard Space Flight Center, USA
- Multi-Global Navigation Satellite Systems (Multi-GNSS) WG, German Aerospace Center (DLR), Germany
- Ionosphere WG, University of Warmia and Mazury, Poland
- Real-Time WG, Bundesamt für Kartographie und Geodäsie, Germany
- Reference Frame WG, Institut National de l'Information Géographique et Forestière, France
- RINEX WG, Natural Resources Canada
- Space Vehicle Orbit Dynamics WG, University College London, United Kingdom
- Troposphere WG, United States Naval Observatory, USA

# Appendix D

## IGS Governing Board & Membership as of 2017

### Governing Board Members as of December 2017

| Status | Name | Affiliation | Country | Role | Service Years |
|---|---|---|---|---|---|
| EC-V | Gary Johnston | Geoscience Australia | Australia | Board Chair | 2010-2018 |
| | Michael Moore | Geoscience Australia | Australia | Analysis Center Coordinator | 2016-2019 |
| EC-V | Chris Rizos | University of New South Wales | Australia | IAG Representative | 2004-2019 |
| V | Carine Bruyninx | Royal Observatory of Belgium<br>Observatoire Royal de Belgique (ORB) | Belgium | IGS Network Representative | 2011-2018 |
| | Ken MacLeod | Natural Resources Canada /<br>Ressources naturelles Canada | Canada | RINEX-RTCM Working Group Chair | 2012-2019 |
| V | Zuheir Altamimi | Institut National de l'Information<br>Géographique et Forestière | France | IAG Representative | 2011-2019 |
| V | Paul Rebischung | Institut National de l'Information<br>Géographique et Forestière | France | IGS Reference Frame Coordinator | 2017-2020 |
| V | Loukis Agrotis | ESA/European Space Operations Centre | Germany | Real-time Analysis Coordinator | 2014-2021 |
| V | Werner Enderle | ESA/European Space Operations Centre | Germany | Appointed (IGS) | 2016-2019 |
| V | Mathias Fritsche | Deutsches GeoForschungsZentrum | Germany | Analysis Center Representative | 2015-2019 |
| | Urs Hugentobler | Technische Universität München | Germany | GNSS Monitoring Working Group Chair | 2011-2021 |
| | Oliver Montenbruck | Deutsches Zentrum für Luft- und Raumfahrt e.V. | Germany | Multi-GNSS Working Group Chair | 2012-2020 |
| | Ignacio Romero | ESA/European Space Operations Centre | Germany | Infrastructure Committee Chair | 2010-2021 |
| | Axel Rülke | Federal Agency for Cartography and Geodesy | Germany | Real-time Working Group, Chair | 2016-2019 |
| V | Laura Sánchez | Deutsches Geodätisches Forschungsinstitut | Germany | Network Representative | 2014-2021 |
| | Ralf Schmid | Deutsches Geodätisches Forschungsinstitut | Germany | Antenna Working Group Chair | 2008-2016 |
| | Tilo Schöne | DeutschesGeoForschungsZentrum Potsdam | Germany | TIGA Working Group Chair | 2001-2020 |
| | Tim Springer | ESA/European Space Operations Centre | Germany | IGMA-IGS Joint GNSS Monitoring and Assessment Trial Project Chair | 2017-2021 |
| V | Satoshi Kogure | National Space Policy Secretariat,<br>Cabinet Office | Japan | Appointed (IGS) | 2014-2019 |
| | Andrzej Krankowski | University of Warmia and Mazury in Olsztyn | Poland | Ionosphere Working Group Chair | 2007-2020 |
| EC-V, IR | Rolf Dach | Astronomical Institute, University of Bern | Switzerland | Analysis Center Representative | 2015-2018 |
| | Arturo Villiger | Astronomical Institute, University of Bern | Switzerland | Antenna Working Group Chair | 2017-2020 |
| | Stefan Schaer | Federal Office of Topography | Switzerland | Bias and Calibration Working Group Chair | 2007-2020 |
| | Marek Ziebart | University College London | UK | Satellite Vehicle Orbit Dynamics Working Group Chair | 2011-2020 |
| V | David Stowers | Jet Propulsion Laboratory | USA | Data Center Representative | 2017-2021 |
| | Sharyl Byram | United States Naval Observatory | USA | Troposphere Working Group, Chair | 2016-2019 |
| V | Michael Coleman | Naval Research Laboratory | USA | IGS Clock Products Coordinator | 2014-2021 |
| | Allison Craddock | Jet Propulsion Laboratory | USA | IGS Central Bureau Secretariat | 2017-Present |
| V | Shailen Desai | Jet Propulsion Laboratory | USA | Analysis Center Representative | 2012-2019 |
| V | Richard Gross | Jet Propulsion Laboratory | USA | IERS Representative | 2015-2019 |
| V | Thomas Herring | Massachusetts Institute of Technology | USA | Analysis Center Coordinator | 2016-Present |
| | David Maggert | UNAVCO | USA | Network Coordinator | 2015-2019 |
| EC-V, IR | Charles Meertens | UNAVCO | USA | Appointed (IGS) | 2011-2018 |
| EC-V | Ruth Neilan | Jet Propulsion Laboratory | USA | Director of IGS Central Bureau | 1994-Present |
| | Carey Noll | NASA Goddard Space Flight Center | USA | Data Center Working Group Chair | 2006-2019 |

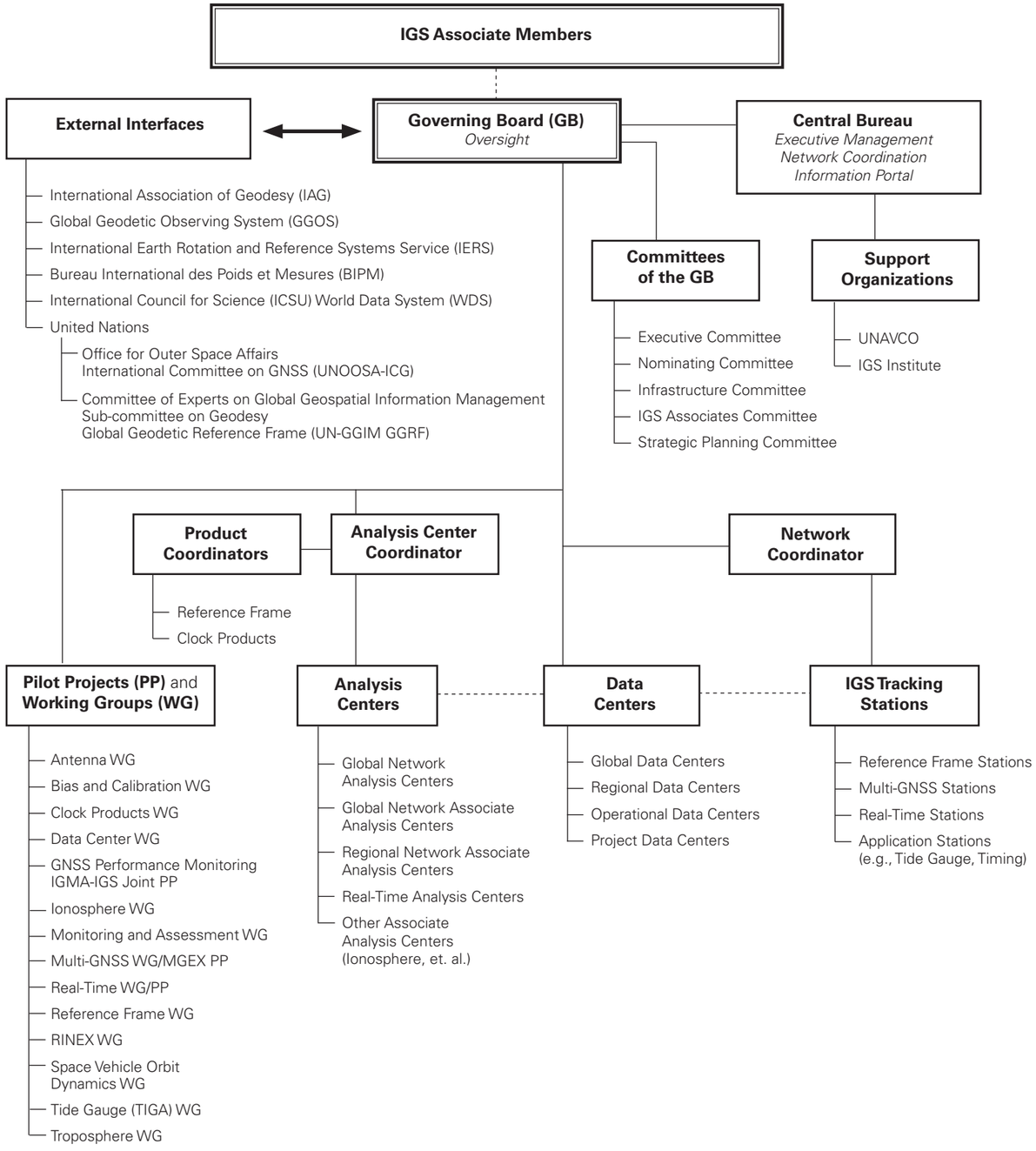
*For current membership lists, including IGS Associate Members, please visit the IGS website: http://www.igs.org/about/am*

### Former Governing Board Members as of December 2017

| | Affiliation | Country | Service Years |
|---|---|---|---|
| John Manning | Geoscience Australia<br>(formerly Australian Survey and Land Information Group) | Australia | 1996-2003 |
| Robert Weber | Vienna University of Technology | Austria | 2003-2012 |
| Paul Paquet | Royal Observatory of Belgium | Belgium | 1999-2002 |
| Norman Beck | Natural Resources Canada | Canada | 2003-2009 |
| Mark Caissy | Natural Resources Canada / Ressources naturelles Canada | Canada | 2001-2015 |
| Remi Ferland | Natural Resources Canada / Ressources naturelles Canada | Canada | 1999-2009 |
| Jan Kouba | Natural Resources Canada / Ressources naturelles Canada | Canada | 1994-1999 |
| Weijun Gan | China Earthquake Administration,<br>Crustal Motion Observation Network of China | China | 2007-2010 |
| Peizhen Zhang | China Earthquake Administration, Institute of Geology | China | 2002-2005 |
| Yamin Dang | Chinese Academy of Surveying and Mapping | China | 2012-2015 |
| Felicitas Arias | Bureau International des Poids et Mesures | France | 2005-2017 |
| Claude Boucher | Institut National de l'Information Géographique et Forestière | France | 1994-2015 |
| Loic Daniel | Institut National de l'Information Géographique et Forestière | France | 2002-2005 |
| Bruno Garayt | Institut National de l'Information Géographique et Forestière | France | 2010-2017 |
| Pascal Willis | Institut National de l'Information Géographique et Forestière | France | 1999 |
| Martine Feissel | International Earth Rotation Service | France | 1994-1995 |
| Nicole Capitaine | Paris Observatory | France | 2004-2008 |
| Ralf Schmid | Deutsches Geodätisches Forschungsinstitut | Germany | 2008-2016 |
| Henno Boomkamp | ESA/European Space Operations Center | Germany | 2003-2010 |
| John Dow | ESA/European Space Operations Center | Germany | 1994-2011 |
| Joachim Feltens | ESA/European Space Operations Center | Germany | 1998-2002 |
| Gerd Gendt | GeoForschungsZentrum Potsdam | Germany | 2003-2007 |
| Christoph Reigber | GeoForschungsZentrum Potsdam | Germany | 1994-2005 |
| Markus Rothacher | GeoForschungsZentrum Potsdam | Germany | 2000-2007 |
| Teruyuki Kato | Earthquake Research Institute, University of Tokyo | Japan | 1994-1995 |
| Bjorn Engen | Norwegian Mapping Authority (Statens Kartverk) | Norway | 1994-2001 |
| Richard Wonnacott | Chief Directorate: National Geo-spatial Information | South Africa | 2006-2013 |
| James Park | Korean Astronomy and Space Science Institute | South Korea | 2010-2013 |
| Manuel Hernandez | Universitat Politecnica de Catalunya | Spain | 2002-2007 |
| Gerhard Beutler | Astronomical Institute, University of Bern | Switzerland | 1994-2011 |
| David Pugh | Southampton Oceanography Centre | UK | 1996-2004 |
| Bob Schutz | Center for Space Research,<br>University of Texas-Austin | USA | 1994-1997 |
| Steven Fisher | IGS Central Bureau, Jet Propulsion Laboratory | USA | 2008-2017 |
| Angelyn Moore | IGS Central Bureau, Jet Propulsion Laboratory | USA | 1998-2007 |
| Yoaz Bar-Sever | Jet Propulsion Laboratory (JPL) | USA | 2003-2011 |
| Bill Melbourne | Jet Propulsion Laboratory (JPL) | USA | 1994-1999 |
| Michael Watkins | Jet Propulsion Laboratory (JPL) | USA | 1999-2001 |
| Jim Zumberge | Jet Propulsion Laboratory (JPL) | USA | 2000-2007 |
| Bob King | Massachusetts Institute of Technology | USA | 2008-2011 |
| Robert Serafin | National Center for Atmospheric Research | USA | 1998-2005 |
| Kevin Choi | National Geodetic Survey (NOAA) | USA | 2014-2015 |
| Gerald Mader | National Geodetic Survey,<br>National Oceanic and Atmospheric Administration | USA | 1994-1997 |
| Jim Ray | National Geodetic Survey,<br>National Oceanic and Atmospheric Administration | USA | 1997-2003,<br>2008-2011 |
| Jim Slater | National Geospatial-Intelligence Agency | USA | 1997-2005 |
| Ken Senior | Naval Research Laboratory | USA | 2003-2012 |
| Ivan Mueller | Ohio State University | USA | 1994-1999 |
| Yehuda Bock | Scripps Institution of Oceanography | USA | 1994-1999 |
| Peng Fang | Scripps Institution of Oceanography | USA | 2004-2005 |
| Fran Boler | UNAVCO | USA | 2014-2017 |
| Christine Hackman | United States Naval Observatory | USA | 2011-2015 |
| Bill Kuo | University Consortium for Atmospheric Research | USA | 2006-2009 |
| Mike Bevis | University of Hawaii | USA | 1998-2001 |
| Geoff Blewitt | University of Nevada - Reno | USA | 2008-2011 |

# Appendix E

## IGS Organization Structure & Inter-Organizational Relations




# Appendix F

## Product Availability Standards & Quality of Service

**IGS Product Availability**

| | Target | 2013 | 2014 | 2015 | *2016 |
|---|---|---|---|---|---|
| **GPS Satellite Ephemerides / Satellite and Station Clocks** | | | | | |
| Ultra-Rapid (predicted half) | 95% | 99.25% | 99.40% | 99.70% | 99.86% |
| Ultra-Rapid (observed half) | 95% | 99.25% | 99.40% | 99.40% | 99.86% |
| Rapid | 95% | 99.25% | 99.40% | 99.70% | 100.00% |
| Final | 99% | 100.00% | 100.00% | 100.00% | 100.00% |
| Real-time | 95% | 99.69% | 100.00% | 100.00% | 100.00% |
| **GLONASS Satellite Ephemerides** | | | | | |
| Final | 99% | 100.00% | 100.00% | 100.00% | 100.00% |
| **Geocentric Coordinates of IGS Tracking Stations** | | | | | |
| Positions of Real-time Stations | 99% | 100.00% | 100.00% | 100.00% | 100.00% |
| Final Positions | 99% | 100.00% | 100.00% | 100.00% | 100.00% |
| Final Velocities | 99% | 100.00% | 100.00% | 100.00% | 100.00% |
| **Earth Rotation Parameters** | | | | | |
| Ultra-Rapid (predicted half) | 99% | 99.25% | 99.40% | 99.70% | 99.86% |
| Ultra-Rapid (observed half) | 99% | 99.25% | 99.40% | 99.70% | 99.86% |
| Rapid | 99% | 100.00% | 100.00% | 100.00% | 100.00% |
| Final | 99% | 100.00% | 100.00% | 100.00% | 100.00% |
| **Atmospheric Parameters** | | | | | |
| IGS Final Tropospheric | 99% | 100.00% | 100.00% | 100.00% | 100.00% |
| Ionosphere TEC Grid | 99% | 100.00% | 100.00% | 100.00% | 100.00% |
| Rapid ionosphere TEC Grid | 95% | 100.00% | 100.00% | 100.00% | 100.00% |

(1) Availability = percentage of time that accuracy, latency and continuity of service meet target specification

(2) Analysis Coordination responsibility transitioned from NGS to GA/MIT January 2016

(3) 2016 saw fewer IT related failures than in previous years (redundant cloud based servers)

# Appendix H

## Glossary of Acronyms

| | |
|---|---|
| **AAC** | Associate Analysis Center |
| **AC** | Analysis Center |
| **AFREF** | African Geodetic Reference Frame |
| **AS** | anti-spoofing |
| **BIPM** | Bureau International des Poids et Mesures, France |
| **CB** | (IGS) Central Bureau |
| **DC** | Data Center |
| **ERP** | Earth rotation parameter |
| **EUREF** | European Reference Frame |
| **FAGS** | Federation of Astronomical and Geophysical Data Analysis Services |
| **GB** | (IGS) Governing Board |
| **GDC** | Global Data Center |
| **GGRF** | Global Geodetic Reference Frame (United Nations) |
| **GEO** | Group on Earth Observations |
| **GEOSS** | Global Earth Observing System of Systems |
| **GGOS** | Global Geodetic Observing System |
| **GIS** | Geographic Information Systems |
| **GLONASS** | Globalnaya Navigatsionnaya Sputnikovaya Sistema (Global Navigation Satellite System). Russia |
| **GLOSS** | Global Sea Level Observing Systems |
| **GNAAC** | Global Network Associate Analysis Center |
| **GNSS** | Global Navigation Satellite System |
| **GPS** | Global Positioning System |
| **IAG** | International Association of Geodesy |
| **ICG** | (United Nations) International Committee on GNSS |
| **ICSU** | International Council of Science |
| **ICSU-WDS** | World Data System of the International Council for Science |
| **IERS** | International Earth Rotation Service |
| **IGLOS-PP** | International GLONASS Pilot Project |
| **IGMA** | International GNSS Monitoring and Assessment |
| **IGS** | International GNSS Service, formerly the International GPS Service |
| **ISO** | International Organization for Standardization |
| **ITRF** | International Terrestrial Reference Frame |
| **ITRS** | International Terrestrial Reference System |
| **IUGG** | International Union of Geodesy and Geophysics |
| **NASA** | National Aeronautics and Space Administration, USA |
| **NAVSTAR** | Navigation System Timing and Ranging |
| **NRCan** | Natural Resources Canada |
| **PBO** | United States Plate Boundary Observatory GPS Network |
| **PNT** | position, navigation, and timing |
| **QZSS** | Quasi-Zenith Satellite System, Japan |
| **RINEX** | Receiver-Independent Exchange format |
| **RNAAC** | Regional Network Associate Analysis Center |
| **SINEX** | Software-Independent Exchange format |
| **SIRGAS** | Sistema de Referencia Geocéntrico para América del Sur (South American Geocentric Reference System) |
| **SME** | Subject-Matter Expert |
| **SPC** | Strategic Planning Committee |
| **SWOT** | Strengths, Weaknesses, Opportunities, and Threats |
| **TDAF** | Tracking and Data Analysis Facility |
| **TEC** | total electron content |
| **TIGA** | Tide Gauge Project |
| **ToR** | Terms of Reference |
| **UN** | United Nations |
| **UN GGIM** | United Nations Committee of Experts on Global Geospatial Information Management |
| **UNOOSA** | United Nations Office for Outer Space Affairs |
| **USGS** | U.S. Geological Survey |
| **USNO** | United States Naval Observatory |
| **UTC** | Coordinated Universal Time |
| **VLBI** | very long baseline radio interferometry |
| **WDC** | World Data Center |
| **WRMS** | weighted root mean square |
| **ZPD** | Zenith Path Delay |