



International GNSS Service

IGS is a service of:



Global Geodetic Observing System
International Association of Geodesy



International Union of Geodesy and Geophysics



International Council for Science
World Data System



National Aeronautics and
Space Administration

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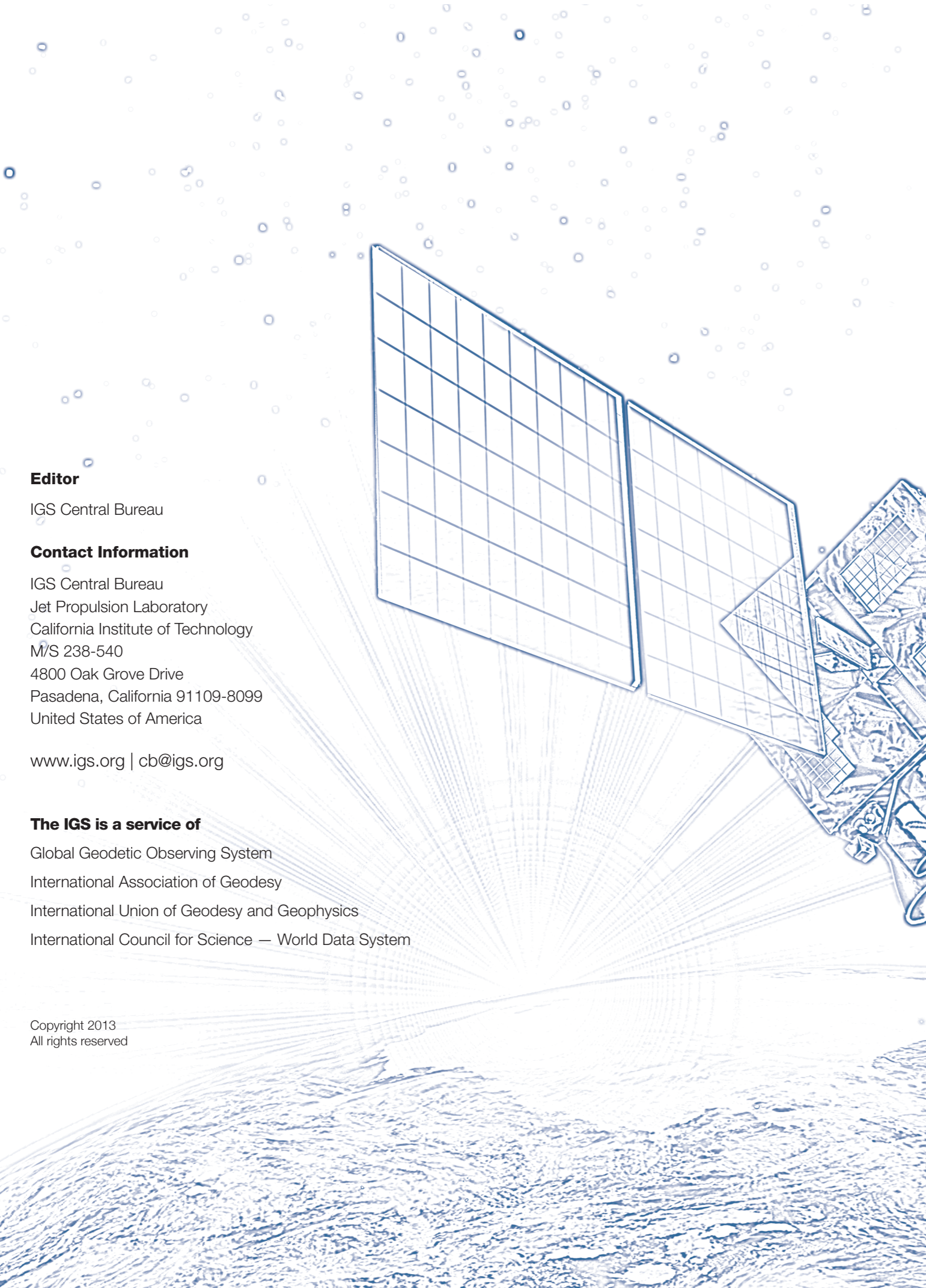
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INTERNATIONAL GNSS SERVICE

Progress Report 2008-2012



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International Council for Science — World Data System

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INTERNATIONAL GNSS SERVICE

Progress Report

IGS Central Bureau
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The IGS mission is to provide the highest-quality GNSS data, products, and services in support of the terrestrial reference frame, Earth observations and research, Positioning, Navigation and Timing (PNT), and other applications that benefit the scientific community and society.

IGS Summary & Introduction

Summary

The International GNSS Service (IGS) conducted an evaluation of progress made in achieving the goals and objectives outlined in the IGS 2008–2012 Strategic Plan. This report concludes that significant progress has been made in areas highly relevant to organizational goals. A summary of the analysis is included herein.

Introduction

The International Global Navigation Satellite System Service (IGS) is a service of the International Association of Geodesy (IAG), which is a member association of the International Union of Geodesy and Geophysics (IUGG). It is also a service of the World Data System of the International Council for Science (ICSU/WDS).

The IGS is a federation of over 216 organizations from around the world. This federation pools its resources to operate a cooperative global infrastructure that provides high-quality Global Navigation Satellite System (GNSS) data products to support high-accuracy positioning, navigation, and timing applications. This IGS product suite enables access to the definitive global reference frame for scientific, educational, and commercial applications.

The IGS carries out its mission through a network of GNSS Tracking Stations, Data Centers, and Analysis Centers that are operated cooperatively by participants around the world. The IGS is governed by an international Governing Board that is elected by Associate Members, the principal participants of the IGS. Executive management of the IGS is carried out by the Central Bureau, as is coordination of the IGS Tracking Network and management of the IGS web

The IGS impacts are measured in terms of societal benefit. By fulfilling its mission to provide the highest quality GNSS data products, the IGS enables broad applications that enhance our understanding of the Earth, improve safety, and promote efficiency.

portal that provides centralized access to IGS products and information. IGS products are generated by combining results from the different Analysis Centers under the direction of the Analysis Coordinator (ACC) and specific product coordinators. Introduction of new products and specific technical issues are addressed through Pilot Projects and Working Groups of technical experts.

IGS data products are openly available to all users. They include GNSS satellite ephemerides, Earth rotation parameters, global tracking station coordinates and velocities, satellite and tracking station clock information, differential code biases for satellites and receivers, zenith troposphere path delay estimates, and global ionosphere information. These products contribute to the realization of the International Terrestrial Reference Frame (ITRF) to which all Earth observations are referenced, and are used in monitoring Earth orientation parameters that are used for relating terrestrial and celestial coordinate systems.

The 2008–2012 Strategic Plan and IGS Technical Reports are available online at www.IGS.org.

IGS Strategic Plan Goals & Objectives

To facilitate the analysis of IGS progress, this report reorganizes goals and strategies that were defined in the 2008–2012 Strategic Plan into a concise set of goals and objectives shown in Table 1 and described below.

Table 1: IGS Goals and Objectives

Goals	Objectives
G1 (World Standard)	O1.1 (Ensure/Increase Quality)
	O1.2 (Meet New User Needs)
	O1.3 (Maintain IGS/GNSS Integration)
	O1.4 (Generate/Advocate GNSS Standards)
	O1.5 (Increase Customer Footprint)
G2 (Expert Advisory Role)	O2.1 (Maintain/Increase Expertise)
	O2.2 (Maintain/Increase Policy Advisory Role)
G3 (Governance & Development)	O3.1 (Governance Best Practices)
	O3.2 (Increase Funding)

- Goal 1 (World Standard)** Serve as the premier source of high-quality GNSS data, products, and standards, freely available to all user communities.
- Objective 1.1 (Ensure/increase quality): Ensure that the quality of GNSS data, products, and services meets or exceeds the present technical quality standards and that the accuracy of the IGS products continues to be improved.*
- Objective 1.2 (Meet new user needs): Incorporate and integrate new systems, technologies, applications, and changing user needs into IGS products and services.*
- Objective 1.3 (IGS/GNSS Integration): Facilitate the integration of IGS into the Global Geodetic Observing System (GGOS) and other broadly based Earth-observing and global navigation systems and services.*
- Objective 1.4 (GNSS Standards): Establish, evolve, and disseminate GNSS world standards.*
- Objective 1.5 (Customers): Increase user footprint and customer satisfaction.*

- Goal 2 (GNSS Expertise and Policy Advisory Role)** Promote the value and benefit of IGS to society, the broader scientific community, and in particular to policy makers and funding entities.
- Objective 2.1 (Technical Expertise): Maintain and increase the technical expertise in all areas of IGS.*
- Objective 2.2 (Policy Making): Maintain and increase IGS presence in policy-making entities.*
- Goal 3 (Governance and Funding Development)** The IGS will maintain and improve the efficiency of its governance and management to support the goals set forth in this strategic plan. This includes the development of funding to support the year-to-year implementation of this plan.
- Objective 3.1 (Best Practices): IGS will continue to incorporate best practices to maintain and improve its efficiency.*
- Objective 3.2: IGS will increase its funding year-to-year and the diversity of its funding sources.*

IGS Achievements

The IGS has made many significant achievements during the 2008–2012 timeframe. These represent the products of the actions in which the IGS has engaged in support of its goals and objectives. Many of the most important achievements are listed in Table 2 and are highlighted in the following pages.

Table 2: IGS Achievements 2008–2012

- 2008

IGS Workshop, Miami, USA
- 2008

New Analysis Center GRGS, Toulouse, France
- 2008

Bias and Calibration Working Group established
- 2008

Antenna Working Group established
- 2008

ACC2.0 Next Generation Combination Software call issued
- 2008

Governing Board begins annual Strategic Implementation Plan process
- 2008

Third meeting of the International Committee on GNSS hosted by IGS CB
- 2008

Infrastructure Committee formed
- 2008

IGS Institute formed
- 2009

First IGS Official Reprocessed results (Repro1) provided to IERS
- 2009

IGS co-chairs ICG WG on Reference Frame, Timing, and Applications
- 2009

IGS becomes RTCM SC104 voting member
- 2009

IGS Institute Public Benefit Corporation status approved by US IRS
- 2010

IGS Workshop, Newcastle upon Tyne, UK
- 2010

TIGA Pilot Project transition into TIGA Working Group
- 2010

Space Vehicle Orbit Dynamics Working Group formed
- 2010

IGS Associates Committee formed/Member selection process reviewed
- 2010

IGS Terms of Reference revised
- 2010

IERS releases ITRF2008 with significant input from IGS
- 2011

Multi-GNSS Global Experiment initiated (M-GEX)
- 2011

First Reprocessing Campaign finalized (Repro1)
- 2011

Migration of IGS Time Scale generation to version 2.0 algorithm
- 2011

IGS08 Reference Frame introduced
- 2011

New antenna model introduced (igs08.atx)
- 2011

Uncalibrated Radome Experiment initiated
- 2011

Technical Report process reintroduced by AIUB
- 2012

IGS Workshop on GNSS Biases, Bern, Switzerland
- 2012

RINEX Working Group formed
- 2012

New Analysis Center, Wuhan University, China
- 2012

All Working Group Charters and memberships reviewed
- 2012

IGS Workshop, Olsztyn, Poland
- 2012

New Site Guidelines adopted
- 2012

Preparations for introduction of IGS Real-time Service in progress
- 2012

Second Reprocessing Campaign initiated (Repro2)
- 2012

ACC2.0 development plan formed
- 2012

IGS co-chairs IGMAS task force within ICG

IGS Highlighted Achievements

■ Core Product Quality

The IGS Analysis Centers have continued to improve product precision and consistency. IGS “final” orbits now agree at a level of approximately 2 cm, and final satellite clock solutions agree at approximately 75 ps RMS with 20 ps standard deviation. The final X- and Y-pole solutions agree at approximately 0.03 mas, and the final length-of-day solutions agree at approximately 0.01 μ s (see <http://www.igs.org/components/prods.html>).

Principal objective supported by this accomplishment: O1.1 Ensure/increase quality.

■ Tracking Network

The IGS network has expanded from 410 to 440 stations since 2008. Many stations have been upgraded to support multiple GNSSs. The number of stations delivering real-time streamed data to IGS has increased from approximately 40 in 2008 to 188 currently, though many of these are being provided on an experimental basis and have not yet been fully integrated within the network. Issues with the decay of available reference frame stations have been partially addressed by the Reference Frame Working Group and Infrastructure Committee.

Objectives supported by this accomplishment: O1.1 Ensure/increase quality, O1.2 Meet new user needs, O1.3 Maintain IGS/GNSS integration, O1.4 Generate/advocate GNSS standards, O1.5 Increase customer footprint.

■ IGS08 Reference Frame

The IGS has adopted the new IGS08 reference frame, which is closely related to ITRF2008. IGS08 is based on a selected globally distributed subset of 232 well-performing ITRF2008 ground stations. Details relating to IGS08 are contained in IGSMAIL-6354 (see <http://igs.org/pipermail/igsmail/>).

Objectives supported by this accomplishment: O1.1 Ensure/increase quality, O1.4 Generate/advocate GNSS standards.

■ Antenna Calibration Model

The IGS has formed an Antenna Working Group to focus on antenna calibration issues. Coincident with the IGS08 Reference Frame release, the IGS adopted a new antenna phase center model (igs08.atx) based on updated absolute calibrations of the ground antennas. Satellite antenna phase center offsets were readjusted to the ITRF2008 scale.

Objectives supported by this accomplishment: O1.1 Ensure/increase quality, O1.4 Generate/advocate GNSS standards.

■ Reprocessing Campaigns

Results of the first IGS reprocessing campaign (Repro1) covering the period 1994–2007 were announced in April 2010 (see IGSMAIL-6136). Repro1 results served as the IGS contribution to ITRF2008, and related product files have been finalized and distributed to the IGS Global Data Centers for access by users. Details relating to the Repro1 Campaign are available online at <http://acc.igs.org/reprocess.html>. A second

reprocessing campaign (Repro2) has been initiated in 2012 to include updated procedures and data since Repro1. Repro2 results will be used in the generation of ITRF2013.

Objectives supported by this accomplishment: O1.1 Ensure/increase quality, O1.3 Maintain IGS/GNSS integration, O1.4 Generate/advocate GNSS standards.

■ Multi-GNSS Global Experiment (M-GEX)

A focused Multi-GNSS experiment was initiated by the GNSS Working Group. M-GEX was developed to establish a data set of new GNSS signals, including the new GPS signals, new Russian GLONASS signals, the Japanese QZSS, the Chinese BeiDou, and the European Union’s Galileo, for experimentation. Participating stations are anticipated to eventually form the core of a multi-GNSS IGS network and service.

Objectives supported by this accomplishment: O1.2 Meet new user needs, O1.3 Maintain IGS/GNSS integration, O1.4 Generate/advocate GNSS standards, O1.5 Increase customer footprint, O2.2 Maintain/increase policy advisory role.

■ Real-time Pilot Project

The strategy for an IGS real-time service has been developed with introduction of an initial service targeted by early 2013. Real-time protocols and station standards have been developed by the Real-time Pilot Project participants working in cooperation with the Infrastruc-

ture Committee. Standards for the real-time GNSS messages are being promoted in cooperation with the Radio Technical Commission for Maritime Services, Subcommittee on Differential GNSS (RTCM-SC104), which is the principal international standards organization for real-time GNSS services. There are 188 stations and 10 Analysis Centers participating in the Real Time Pilot Project. Additionally, a GPS World article was published in June 2012.

Objectives supported by this accomplishment: O1.2 Meet new user needs, O1.3 Maintain IGS/GNSS integration, O1.4 Generate/advocate GNSS standards, O1.5 Increase customer footprint, O2.2 Maintain/increase policy advisory role.

■ Infrastructure Committee

The IGS has formed an Infrastructure Committee to focus on improving the network as well as data product and information delivery systems.

Objectives supported by this accomplishment: O1.1 Ensure/increase quality, O1.4 Generate/advocate GNSS standards.

■ Receiver Independent Exchange Format (RINEX) Working Group

A RINEX Working Group has been established to assume leadership in maintenance and further development of RINEX. The group’s main tasks include working in cooperation with RTCM-SC104 to establish RINEX3 as a standard for new sig-

nals and GNSS systems; developing and implementing a transition plan to the new format as well as encouraging and supporting the development of open software tools for data handling and quality control.

Objectives supported by this accomplishment: O1.1 Ensure/increase quality, O1.2 Meet new user needs, O1.3 Maintain IGS/GNSS integration, O1.4 Generate/advocate GNSS standards, O1.5 Increase customer footprint, O2.2 Maintain/increase policy advisory role.

■ Tide Gauge Working Group

The TIGA project has transitioned from pilot phase to an official IGS product.

Objectives supported by this accomplishment: O1.1 Ensure/increase quality, O1.2 Meet new user needs, O1.3 Maintain IGS/GNSS integration, O1.5 Increase customer footprint, O2.1 Maintain/increase expertise.

■ Space Vehicle and Orbit Dynamics Working Group

The IGS has formed a new Satellite Orbit and Dynamics Working Group to develop improved satellite radiation pressure models. These improved models are expected to improve the quality of the IGS orbit products.

Objectives supported by this accomplishment: O1.1 Ensure/increase quality, O1.4 Generate/advocate GNSS standards, O2.1 Maintain/increase expertise.

■ Bias and Calibration Working Group

The IGS has formed a new Bias and Calibration Working Group to coordinate research related to bias retrieval, analysis, and monitoring. This Working Group is expected to develop procedures for consistent handling of biases between different GNSS receiver types and constellations.

Objectives supported by this accomplishment: O1.1 Ensure/increase quality, O1.3 Maintain IGS/GNSS integration, O1.4 Generate/advocate GNSS standards, O2.1 Maintain/increase expertise.

■ Troposphere Working Group

The Troposphere product has transitioned from pilot phase to an official IGS product. Daily zenith path delay estimates are being generated by the United States Naval Observatory with an approximate three-week latency for all active IGS sites based on Precise Point Positioning techniques. IGS Final Troposphere estimates are used by scientists worldwide to support climate-change and meteorological studies; 17.3 million Estimates files were downloaded in 2012 alone.

The goal of the Troposphere Working Group (TWG) is to improve the accuracy and usability of IGS troposphere estimates. The TWG goal for 2012–2014 is to automate/publish comparisons of troposphere estimates obtained using independent methods including satellite geodesy, radio astronomy, and radiosondes. Coordination of IGS troposphere

activities — including computation of IGS Final Troposphere Estimates and chairpersonship of the IGS TWG — was transferred in 2011 from the NASA Jet Propulsion Laboratory (Pasadena, California, USA) to the United States Naval Observatory (Washington, DC, USA).

Objectives supported by this accomplishment: O1.1 Ensure/increase quality, O1.2 Meet new user needs, O1.3 IGS/GNSS integration; O1.4 GNSS standards, O1.5 Customers, O2.1 Technical expertise, O2.2 Policy making.

■ Combination Software

Plans have been developed to update the IGS combination software jointly by the CODE and ESOC analysis centers together with TU Vienna. This is the first major revision of this software since IGS began generating combination products in 1994. It is envisioned to allow for Multi-GNSS product combination and improve traceability of IGS products and maintainability of the software.

Objectives supported by this accomplishment: O1.1 Ensure/increase quality, O1.2 Meet new user needs, O1.3 Maintain IGS/GNSS integration.

■ Site Guidelines

IGS Site Guidelines have been continuously revised to reflect currently recommended best practices. Guidelines were revised in 2012 to include procedures for upgrading station equipment, prescribing

periods of operation where old and new equipment are operated simultaneously to assure that discontinuities are properly mapped, as well as guidelines for real-time stations. In 2009, stricter ground antenna requirements were added to the Guidelines, as recommended by the Antenna Working Group during the 2008 IGS Workshop.

Objectives supported by this accomplishment: O1.1 Ensure/increase quality, O1.3 Maintain IGS/GNSS integration, O1.4 Generate/advocate GNSS standards.

■ Radome Experiment

An experiment to assess the effects of 21 IGS stations that are co-located with SLR or VLBI sites where radomes have not been calibrated to IGS standards has been initiated. Station operators at many of these stations have removed radomes for a two-month period to a data set for experimentation. Analysis is in progress.

Objectives supported by this accomplishment: O1.1 Ensure/increase quality, O1.3 Maintain IGS/GNSS integration, O1.4 Generate/advocate GNSS standards.

■ Network Information Systems

IGS network information systems are in process of being upgraded to improve information content and consistency. A prototype IGS network interface, which provides better access to station data and quality control (QC) information, is now operating. Site log metadata are now contained in a relational database

operating in parallel to the current site log system, which is facilitating improvements in site metadata accuracy and accessibility. Network performance monitoring reports are being derived from metadata and quality control information that give an aggregate view of the network's performance, including threshold compliance with IGS guidelines, data availability and quality parameters.

Objectives supported by this accomplishment: O1.1 Ensure/increase quality, O1.4 Generate/advocate GNSS standards.

■ IGS Workshops

Several IGS Workshops have been conducted since 2008:

- Community Workshop, Miami, USA, 2008. <http://www.ngs.noaa.gov/IGSWorkshop2008/>
- Community Workshop, Newcastle, UK, 2010. <http://www.igs.org/event/newcastle2010/>
- TIGA Workshop, 2010.
- Bias and Calibration Workshop, Bern, Switzerland, 2012. <http://www.biasws2012.unibe.ch/>
- Community Workshop, Olsztyn, Poland, 2012. <http://igs.org/presents/poland2012/>

Objectives supported by this accomplishment: O1.1 Ensure/increase quality, O1.2 Meet new user needs, O1.3 Maintain IGS/GNSS Integration, O1.4 Generate/advocate GNSS Standards, O1.5 Increase customer footprint, O2.1 Maintain/Increase Expertise, O2.2 Maintain/Increase Policy Advisory role, O3.1 Governance best practices, O3.2 Increase funding.

■ IGS Publications

A number of IGS publications have been produced since 2008, including:

- IAG Travaux Reports, biennially.
- IGS Section of the IERS Annual Reports.
- Special IGS issue of the Journal of Geodesy. <http://www.springerlink.com/content/0949-7714/83/3-4/>
- White papers covering RINEX 2.12 and 3.01 were written in 2009.
- “A Guide to Using IGS Products” was significantly updated in 2009. <http://igs.org/igsacb/resource/pubs/UsingIGSProductsVer21.pdf>
- IGS Technical Reports since 2011. ftp://igs.org/pub/resource/pubs/2011_techreport.pdf
- TIGA paper published in Journal of Geodesy. http://acc.igs.org/trf/tiga_jog09.pdf
- Real-time article published in GPS World, June 2012. <http://bit.ly/RTgpsworld>
- IGS Antenna Phase Center Corrections article published in GPS World Tech Talk Blog. http://acc.igs.org/antennas/igs-pcvs_gpsworld10.pdf
- IGS08: the IGS realization of ITRF2008. <http://dx.doi.org/10.1007/s10291-011-0248-2>

Objectives supported by this accomplishment: O1.4 Generate/advocate GNSS standards, O1.5 Increase customer footprint, O2.1 Maintain/increase expertise, O2.2 Maintain/increase policy Advisory role, O3.1 Governance best practices, O3.2 Increase funding.

■ Compilation of Works Citing IGS

Many papers, articles, and presentations relating to IGS have been published or presented. A partial listing of these is available online at <http://tinyurl.com/IGS-bibli>.

Objectives supported by this accomplishment: O1.4 Generate/advocate GNSS Standards, O1.5 Increase customer footprint, O2.1 Maintain/increase expertise, O2.2 Maintain/increase policy advisory role, O3.1 Governance best practices, O3.2 Increase funding.

■ External Coordination and Outreach

The IGS coordinates extensively with many external organizations to promote the IGS and develop key partnerships with participants and users:

- International Association of Geodesy/Global Geodetic Observing System (IAG/GGOS): The IGS coordinates extensively with GGOS, including membership of the Coordinating Board and within the Bureau for Networks and Communications.
- United Nations/International Committee on GNSS (ICG): Working Group D on Reference Frames, Timing, and Applications is co-chaired by the IGS CB Director, as is the International GNSS Monitoring and Assessment System (IGMAS) Task Force. The annual ICG Meeting is typically attended by several IGS participants.
- International Earth Rotation and Reference Systems Service (IERS): IGS and IERS have con-

tinued to extensively cooperate in the realization of ITRF, as well as reciprocally participate on each other's boards.

- Radio Technical Commission for Maritime Services, Subcommittee on Differential GNSS (RTCM-SC104): The IGS holds voting membership on this international standards organization for Differential GNSS, and chairs the RINEX WG.
- International Federation of Surveyors (FIG): FIG represents the single largest user community of IGS products, and is also a potential channel for extending the IGS network. IGS and FIG are coordinating to reach out to users, as well as to advocate for precision geodesy within organizations such as the ICG.
- Regional Reference Frame Activities: The IGS coordinates extensively at multiple levels with regional reference frame activities, such as AFREF, SIRGAS, APREF, NAREF, and EUREF.
- Sea Level Activities: Through the Tide Gauge Working Group, IGS participates within the Global Sea Level Observing System (GLOSS) to precisely locate tide gauges within the ITRF.

Additionally, IGS has reached out to many user communities representing different regions and disciplines by participating in scientific workshops and conferences with presentations and chairing of sessions. Examples of conference and workshops attended include: AfricaGEO, the International Council of Science/World

Data System (WDS), the American Geophysical Union (AGU) and European Geosciences Union (EGU), the International Union of Geodesy and Geophysics (IUGG), the International Association of Geodesy (IAG), the Asia Oceania Geosciences Society, the U.S. Institute of Navigation, the China Satellite Navigation Conference, and the Colloquium on Scientific Applications of Galileo, among others.

Objectives supported by this accomplishment: O1.1 Ensure/increase quality, O1.2 Meet new user needs, O1.3 Maintain IGS/GNSS integration, O1.4 Generate/advocate GNSS standards, O1.5 Increase customer footprint, O2.1 Maintain/increase expertise, O2.2 Maintain/increase policy advisory role, O3.1 Governance best practices, O3.2 Increase funding.

■ Terms of Reference

IGS Terms of Reference, the principal governing document of IGS, has been reviewed in detail and updated by the Governing Board.

Objectives supported by this accomplishment: O3.1 Governance best practices.

■ Working Group Charters and Membership

All Working Group charters and membership have been reviewed for relevancy and to assure the appropriate technical experts remain involved.

Objectives supported by this accomplishment: O1.1 Ensure/increase quality, O1.2 Meet new user needs, O1.4 Generate/advocate GNSS standards, O2.1 Maintain/increase expertise, O3.1 Governance best practices.

■ Associate Membership

The process for selecting the IGS Associate Members has been reviewed and updated by the Governing Board, resulting in the formation of the Associate Membership Committee. The constituency of Associate Members is reviewed annually.

Objectives supported by this accomplishment: O2.1 Maintain/increase expertise, O3.1 Governance best practices.

■ IGS Institute

The IGS Institute was formed under the Central Bureau as a legal entity that is dedicated to furthering the IGS mission. It is considered a charitable organization under US corporate law and thus pays no income tax per the public benefit provision of the US tax code (commonly known as a section 501(c)(3) exemption). The IGS Institute provides a channel through which the IGS can conduct business that is not constrained by the policies or interests of any parent organization that may limit its effectiveness.

Objectives supported by this accomplishment: O1.2 Meet new user needs, O1.3 Maintain IGS/GNSS integration, O1.4 Generate/advocate GNSS standards, O1.5 Increase customer footprint, O2.1 Maintain/increase expertise, O2.2 Maintain/increase policy advisory role, O3.1 Governance best practices, O3.2 Increase funding.

IGS Progress on Defined Actions

Through a Strategic Implementation Planning (SIP) process, the Governing Board specifies detailed actions, based on the actions defined in the Strategic Plan, that serve to steer IGS activities on an annual basis. These are reviewed and evaluated annually, providing a subjective measure of performance. An aggregated summary of the SIP evaluations is included in Appendix 1. Our analysis of these shows that significant progress has been made in all but 5 of the 56 actions that were defined in the 2008–2012 Strategic Plan (Table 3).

Table 3: Activities Where Little or No Progress Was Made

Action No.	Activity Description
8	Obtain user feedback on the quality of services provided and report the results.
16	Develop and distribute open-source, standard software tools for IGS users.
23	Create a “Welcome” package highlighting key aspects of the IGS culture, including examples of IGS spirit of collegiality and collaboration.
24	Utilize university members to serve as “Ambassadors for IGS” within their universities to attract the interest of multi-disciplinary centers.
32	Study and recommend a minimum set of GNSS signals required for scientific data processes.

IGS Impact of Activities

This analysis considered the relevance of IGS activities to the organizational goals and objectives through an Activity Impact Analysis that evaluates impact in three areas (see Appendix 2):

- 1. Impact of achievements.
- 2. Impact of ongoing activities.
- 3. Impact of the IGS components.

Each accomplishment, ongoing activity, and IGS component, collectively the IGS activities, was assigned a relevance rating that relates the activity to each of the IGS objectives, as follows:

- Activity **directly** impacts objective
- Activity **indirectly** impacts objective
- Activity has **minimal** impact on objective

These relevance ratings provide a useful relative measure of the contributions made by the various IGS activities in achieving defined objectives. In total, 76 IGS activities were evaluated. A number of conclusions can be inferred:

- 1. All of the IGS activities evaluated are highly relevant to at least one of the IGS objectives.
- 2. These activities yielded significant impact (218 direct impacts and 278 indirect impacts) in achieving objectives.
- 3. Objectives most directly impacted by the IGS Activities include O1.1 Quality, O1.3 GNSS Integration, and O1.4 Standards.

- 4. Objectives most indirectly impacted by the IGS Activities include O1.4 Standards, O1.5 Increase Customer Footprint, O2.1 Expertise, and O2.2 Policy Advisory Role.
- 5. Objectives least impacted by the IGS Activities (i.e., those with the most number of activities that have minimal impact) include O3.1 Best Practices and O3.2 Funding.
- 6. The 33 accomplishments evaluated had relatively high impact on all objectives except those related to G3 Governance and Development.
- 7. Most of the 24 ongoing activities evaluated had a relatively high impact on all objectives except for O1.2 New user needs and O3.2 Funding.
- 8. The 19 IGS components evaluated have relatively high impact on all objectives except those related to G3 Governance and Development.

Overall, the analysis shows that all of the IGS activities are highly relevant and address all of the defined objectives. All activities also have a significant direct or indirect impact on the IGS objectives. IGS goals most impacted by the IGS Activities include G1 World Standard and G2 Expert Advisory Role, where the objectives relevant to achieving those goals are strongly supported by the IGS activities. Least impacted is G3 Governance and Funding Development, where fewer of the IGS activities support the relevant objectives, suggesting that more future effort should be assigned in these areas.

IGS Effectiveness in Achieving Goals and Objectives

Corresponding to each of the stated objectives, we have defined objective measures that may be used to assess effectiveness (Table 4).

Table 4:
Objective
Targets and
Measure-
ment of
Success

Goals	Objectives	Objective Measurement of Success
G1 (World Standard)	O1.1 (Ensure/Increase Quality)	Improved precision of core products
	O1.2 (Meet New User Needs)	Increase in number of product downloads
	O1.3 (Maintain IGS/GNSS Integration)	Increase IGS participation within Earth observing programs and systems
	O1.4 (Generate/Advocate GNSS Standards)	Adoption of IGS processes as standard
	O1.5 (Increase Customer Footprint)	Increase in user base
G2 (Expert Advisory Role)	O2.1 (Maintain/Increase Expertise)	Increased number of publications that cite IGS
	O2.2 (Maintain/Increase Policy Advisory Role)	Increased IGS participation in policy organizations
G3 (Governance & Development)	O3.1 (Governance Best Practices)	Measured achievement of IGS objectives
	O3.2 (Increase Funding)	Additional funds available

O1.1 Ensure/Increase Quality

The principal measure of success is an improvement in the precision of the IGS core products. Analysis results show that the precision of all of the core products has improved over the past five years.

Result in achieving objective: success.

O1.2 Meet New User Needs

The principal measure of success is an increase in the number of product downloads. Examination of the Central Bureau access (ftp) logs shows an approximate 200% increase in the number of file downloads between 2008 and 2012.

Result in achieving objective: success.

O1.3 Maintain IGS/GNSS Integration

The principal measure of success is an increase in IGS participation within various Earth observing programs and systems. Since 2008, IGS has continued its participation within the World Data System (WDS), initiated participation in the Global Geodetic Observing System (GGOS), and has continued engaging with the different GNSS providers through participation in the United Nations/International Committee on GNSS (ICG).

Result in achieving objective: success.

O1.4 Generate/Advocate GNSS Standards

The principal measure of success is adoption of IGS processes as recognized standards. Since 2008, the IGS has:

- Continued to contribute to the International Terrestrial Reference Frame, which is the de facto standard to which all Earth observations are referenced;

- Developed and almost entirely revised the IGS Site Guidelines, which are highly referenced by GNSS users around the world;
- Initiated participation within the Radio Technical Commission for Maritime Services, Subcommittee on Differential GNSS Services (RTCM-SC104), the principal standards organization for real-time GNSS data for the maintenance and development of the RINEX format;
- Developed real-time GNSS protocols that have been adopted by many organizations worldwide; and compiled a new antenna phase center model that is used widely.

Result in achieving objective: success.

01.5 Increase Customer Footprint

The principal measure of success is an increase in the number of IGS users. The number of distinct visits to the Central Bureau ftp site is one indicator of the number of users, and has increased by approximately 300% between 2008 and 2012.

Result in achieving objective: success.

02.1 Maintain/Increase Expertise

The principal measure of success is an increase in the number of publications that cite IGS. The IGS bibliography shows an increase in number of publications that cite IGS during the 2008–2012 time frame over previous periods (see <http://tinyurl.com/IGS-bibli>).

Result in achieving objective: success.

02.2 Maintain/Increase Policy Advisory Role

The principal measure of success is an increase in IGS participation within policy organizations. Since 2008, the IGS has participated within the International Committee on GNSS (ICG) and within the United States National Positioning, Navigation and Timing (PNT) Executive Advisory Committee.

Result in achieving objective: success.

03.1 Governance and Best Practices

The principal measure of success is an overall achievement of Strategic Plan objectives, as documented within this report.

Result in achieving objective: success.

03.2 Increase Funding

The principal measure of success is an increase in funds available to IGS. Since the IGS is not centrally funded, this cannot be measured directly. However, an increase in the number of IGS participants, who fund their own participation, forms a useful proxy for this metric. An examination of the IGS Associate Membership shows a growing number of participants within IGS.

Result in achieving objective: success.

IGS Conclusions

This report has highlighted many achievements the IGS has made in carrying out activities that support its defined actions. The report has demonstrated that the IGS activities are relevant to the organizational objectives, and has objectively measured effectiveness in achieving objectives. It is concluded from this analysis that the IGS has made significant progress in achieving its goals. In particular, the IGS goals of serving as the premier source of high-quality GNSS data, products, and standards (G1), and promoting the value and benefit of IGS to society and the broader scientific community (G2) are well addressed by the IGS activities. However, it was discovered through this analysis that more work is needed on objectives relating to Governance and Development (G3). It was also decided that all future Progress Reports will be written with the assistance of the outgoing Chair, so that he or she will be able to provide input and guidance throughout the entire writing process.

Appendix 1

Summary of Progress on Defined Actions

- ➔ Progress made
- ⊖ Little or no progress made
- ✓ Action completed

Action #	Defined Action <i>IGS Components that Support Action</i>	Progress
1	Maintain all IGS components at the highest levels of quality and accuracy <i>All Working Groups</i>	➔
2	Compare, combine and validate IGS products <i>Analysis Center Coordinator/Analysis Centers</i>	➔
3	Regularly reanalyze existing IGS tracking data using the most the up-to-date models and standards to generate homogenous and highest-quality time series of products <i>Analysis Center Coordinator, Analysis Centers, Reference Frame Working Group</i>	➔
4	Determine, publish and implement improvements required in the IGS infrastructure, network, hardware, software, analysis techniques and product dissemination <i>Infrastructure committee, Analysis Center Coordinator/Analysis Centers, all Working Groups, Central Bureau, Data Centers, Station Operators</i>	➔
5	Assess, monitor and improve site-related data quality and access to ITRF <i>Infrastructure Committee, Analysis Center Coordinator/Analysis Centers, Central Bureau/Network Coordinator</i>	➔
6	Engage with station operators, Analysis Centers (ACs), researchers and equipment manufacturers to help design standards and conventions, and to train/assist future system builders <i>Central Bureau/Network Coordinator, Infrastructure Committee</i>	➔
7	Review the performance and effectiveness of the overall service through IGS workshops, reviews of the IGS components, and by other means as necessary <i>Governing Board, Central Bureau, Analysis Center Coordinator, all Working Groups</i>	➔
8	Obtain user feedback on the quality of services provided and report the results <i>Governing Board, Central Bureau</i>	⊖
9	Audit and report on areas requiring changes and implement <i>All components</i>	➔
10	Support participating organizations in developing and meeting standards for the transition to a multi-system, multi-GNSS tracking network <i>GNSS Working Group, Analysis Center Coordinator/Analysis Centers, Central Bureau/Network Coordinator, Infrastructure Committee</i>	➔

- ➔ Progress made
- ⊖ Little or no progress made
- ✓ Action completed

Action #	Defined Action <i>IGS Components that Support Action</i>	Progress
11	Provide open access to data and products to meet the needs of IGS user communities <i>Data Centers</i>	➔
12	Identify and pursue innovative projects, and incorporate new technologies and systems <i>Governing Board, All Working Groups</i>	➔
13	Promote the IGS as the world standard via forums, workshops, education and brochures <i>All components</i>	➔
14	Determine user requirements, benefits received, and future needs through special sessions, user workshops, literature search, and university connections; and respond with documentation for sponsors and users <i>All components</i>	➔
15	Incorporate these user needs into the IGS through improved processes, products and services <i>All components</i>	➔
16	Develop and distribute open-source, standard software tools for IGS users <i>Analysis Center Coordinator/Analysis Centers, all Working Groups</i>	⊖
17	Encourage researchers to cite the IGS in journal publications, and apprise editors of IGS citations, including data publishing <i>Governing Board, Central Bureau</i>	➔
18	Outreach and expand to new user communities and GNSSs <i>Governing Board, Central Bureau</i>	➔
19	Build partnerships and participation with governmental, educational and commercial entities <i>Governing Board, Central Bureau</i>	➔
20	Attract talented and new researchers by involving them in challenging science, innovative projects, and engaging with IAG commissions <i>All components</i>	➔
21	Publicize involvement in innovative areas, working groups and projects <i>All components</i>	➔
22	Pursue and engage new participants in different geographic areas, scientific disciplines, and application areas by including them in meetings and workshops, and through focused presentations <i>All components</i>	➔
23	Create a ‘Welcome’ package highlighting key aspects of the IGS culture, including examples of IGS spirit of collegiality and collaboration <i>Governing Board, Central Bureau</i>	⊖
24	Utilize university members to serve as ‘Ambassadors for IGS’ within their universities to attract the interest of multi-disciplinary centers <i>Governing Board, Central Bureau</i>	⊖

- ➔ Progress made
 ⊖ Little or no progress made
 ✓ Action completed

Action #	Defined Action <i>IGS Components that Support Action</i>	Progress
25	Incorporate new systems, signals and technologies into IGS capabilities <i>All components</i>	➔
26	Build relationships and implement plans for including modernized GPS, modernized GLONASS, Galileo, and potentially other emerging systems and augmentations <i>All components</i>	➔
27	Initiate a Galileo Pilot Project once feasible and study the Galileo signals and formats through the GNSS Working Group, working in cooperation with analysis centers <i>Multi-GNSS Working Group, Analysis Center Coordinator/Analysis Centers, Central Bureau/Network Coordinator, Infrastructure Committee</i>	➔
28	Establish strategic alliances and maintain a continuing dialogue to ensure IGS will be integrated into broadly based Earth observation and GNSS organizations such as the Global Geodetic Observing System (GGOS), the International Committee on GNSS (ICG), the Global Earth Observation System of Systems (GEOSS), the developing project Unification of African Reference Frames (AFREF), and others <i>Governing Board, Central Bureau</i>	➔
29	Feed IGS inputs into the Group on Earth Observations (GEO) work plan via GGOS; interrogate the list of GEO tasks, which could lead to new innovative multi-disciplinary projects <i>Governing Board, Central Bureau</i>	➔
30	Define the IGS role in GGOS and formalize and promote interactions with IAG Services through GGOS, and other scientific services as appropriate <i>Governing Board, Central Bureau</i>	➔
31	Be a prime source of GNSS multi-system monitoring supported by corresponding system products <i>GNSS Working Group, Analysis Center Coordinator/Analysis Centers, Central Bureau/Network Coordinator, Infrastructure Committee</i>	➔
32	Study and recommend a minimum set of GNSS signals required for scientific data processes <i>GNSS Working Group, Analysis Coordinator/Analysis Centers</i>	⊖
33	Encourage data centers and analysis centers to confirm ability to store, distribute and analyze additional "evaluation sites" <i>Governing Board</i>	➔
34	Increase IGS processing capacities to include new signals and more frequent delivery of products <i>GNSS Working Group, Analysis Center Coordinator/Analysis Centers</i>	➔
35	Develop new classes of products needed by IGS users, such as products to support real-time tsunami warning systems, Earth and space weather forecasting, precise timing, climate change research, etc. <i>All components</i>	➔

- ➔ Progress made
 ⊖ Little or no progress made
 ✓ Action completed

Action #	Defined Action <i>IGS Components that Support Action</i>	Progress
36	Build broader global participation with nations and regions not actively involved with IGS <i>Governing Board, Central Bureau</i>	➔
37	Conduct joint projects with other services, user groups or organizations <i>All components</i>	➔
38	Promote participation in the IGS real-time activities and encourage upgrade of IGS station capabilities to provide data in real-time; encourage the use of real-time products for emerging applications; engage with GNSS equipment manufacturers to develop highly capable products; and proactively develop relevant standards. <i>Real-time Working Group, Analysis Coordinator/Analysis Centers, Central Bureau/Network Coordinator, Infrastructure Committee</i>	➔
39	Promote the value of the IGS as a primary source of high-precision GNSS information, articulate the IGS benefits, identify activities that are of value to policy and decision makers and provide justification to gain support for on-going funding of participants <i>Governing Board, Central Bureau</i>	➔
40	Broadly promote the current (2008-2012) Strategic Plan through personal communications, newsletters, annual reports, educational forums, workshops, special sessions at meetings or workshops and correspondence <i>Governing Board, Central Bureau</i>	✓
41	Identify funding sources and decision makers and invite them to participate in IGS events <i>Governing Board, Central Bureau</i>	➔
42	Identify multi-year funding opportunities from sponsors; promote IGS benefits and integrate with global initiatives such as GGOS and ICG to strengthen justification for funding commitments <i>Governing Board, Central Bureau</i>	➔
43	Raise funds for specific initiatives and activities, such as reference frame development and training in developing countries <i>Governing Board, Central Bureau</i>	➔
44	Seek additional voluntary commitments from IGS participants. <i>Governing Board, Central Bureau</i>	➔
45	Balance GB meetings between strategic direction and technical issues <i>Governing Board, Central Bureau</i>	➔
46	Improve mechanisms for taking technical and administrative actions required to improve the service <i>Governing Board, Central Bureau</i>	➔
47	Continue its policy of transparency and openness of GB discussions and decisions <i>Governing Board, Central Bureau</i>	➔
48	Ensure diversity of the GB with respect to geographical distribution, expertise and applications. <i>Governing Board, Central Bureau, Associate Members</i>	➔

- ➔ Progress made
- ⊖ Little or no progress made
- ✓ Action completed

Action #	Defined Action <i>IGS Components that Support Action</i>	Progress
49	Establish a process to implement the Strategic Plan and monitor progress <i>Governing Board, Central Bureau</i>	✓
50	Establish annual implementation plan with assigned accountability <i>Governing Board, Central Bureau</i>	✓
51	Develop sources for new and expanded funding to strengthen the CB office <i>Governing Board, Central Bureau</i>	➔
52	Distribute defined functions to other IGS participants and/or make use of visitors where feasible to expand the capabilities of the CB <i>Central Bureau</i>	➔
53	Work with the GB and IGS components to develop priorities and actions for improving the overall effectiveness of the IGS <i>All components</i>	➔
54	Facilitate the establishment of a permanent Infrastructure Committee to advise the Governing Board on matters related to the IGS infrastructure components and to coordinate activities for improving the overall service <i>Central Bureau</i>	✓
55	Establish a legal entity as a model through which the IGS can conduct business with international organizations, industry and the general public <i>Central Bureau</i>	✓
56	Assist the GB in implementing elements of the Strategic Plan, administering the Strategic Plan and monitoring progress on action items <i>Central Bureau</i>	➔

Appendix 2

Achievement Impact Analysis

Key:

Achievement **directly** impacts objective

Achievement **indirectly** impacts objective

Achievement has **minimal** impact on objective

		G1 World Standard					G2 Expert Advisory Role		G3 Governance & Development					
		O1.1 Quality	O1.2 New user needs	O1.3 IGS/GNSS Integration	O1.4 GNSS Standards	O1.5 Customer footprint	O2.1 Expertise	O2.2 Policy Advisory role	O3.1 Best practices	O3.2 Funding	Direct Impact on number of objectives	Indirect Impact on number of objectives	Minimal Impact on number of objectives	Activity Impact Index =direct*9 + indirect*3 + minimal*1
Achievements														
2008	IGS Workshop, Miami										8	1	0	75
2008	Bias and Calibration Working Group established										3	4	2	41
2008	ACC2.0 Next Generation Combination Software call issued										2	5	2	35
2008	Governing Board begins Strategic Implementation Plan process										2	4	3	33
2008	Third meeting of the International Committee on GNSS hosted by CB (ICG-3)										3	5	1	43
2008	Infrastructure Committee formed										4	3	2	47
2008	IGS Institute formed										1	8	0	33
2009	First IGS Official Reprocessed results provided to IERS										2	4	3	33
2009	IGS leads ICG Working Group on Reference Frame and Timing										6	2	1	61
2009	IGS becomes RTCM SC104 voting member										2	5	2	35
2010	IGS Workshop, Newcastle										8	1	0	75
2010	TIGA Pilot Project transition into TIGA Working Group										2	2	5	29
2010	Space Vehicle Orbit Dynamics Working Group Formed										3	2	4	37
2010	IGS Associates Committee formed/Member selection process reviewed										2	0	7	25
2010	IGS Terms of Reference revised										1	8	0	33

Key:

Achievement **directly impacts** objective

Achievement **indirectly impacts** objective

Achievement has **minimal impact** on objective

		G1 World Standard					G2 Expert Advisory Role		G3 Governance & Development		Direct Impact on number of objectives	Indirect Impact on number of objectives	Minimal Impact on number of objectives	Activity Impact Index =direct*9 + indirect*3 + minimal*1
		O1.1 Quality	O1.2 New user needs	O1.3 IGS/GNSS Integration	O1.4 GNSS Standards	O1.5 Customer footprint	O2.1 Expertise	O2.2 Policy Advisory role	O3.1 Best practices	O3.2 Funding				
2010	ITRF 2008 released, with IGS input										2	5	2	35
2011	MultiGNSS Project initiated (M-GEX)										7	2	0	69
2011	First Reprocessing Campaign finalized (Repro1)										2	3	4	31
2011	Troposphere Working Group goal clarification/forward progress										5	2	2	53
2011	IGS08 Reference Frame introduced										2	4	3	33
2011	New antenna model introduced (IGS08.atx)										2	3	4	31
2011	Uncalibrated Radome Experiment initiated										2	3	4	31
2011	Technical Report process introduced										1	8	0	33
2012	IGS Workshop in GNSS Biases, Bern										4	3	2	47
2012	RINEX Working Group Formed										5	2	2	53
2012	All Working Group Charters and memberships reviewed										1	7	1	31
2012	IGS Workshop, Olstzyn										8	1	0	75
2012	New site Guidelines adopted										3	4	2	41
2012	Real-time Service Announced										4	4	1	49
2012	Second Reprocessing Campaign initiated										2	3	4	31
2012	Timing product begins transitioning to production phase										1	5	3	27
2012	ACC2.0 development plan formed										2	5	2	35
2012	IGS leads IGMAS task force within ICG										6	1	2	59
Sum											108	119	70	
Number of achievements directly impacting objective		11	9	18	20	7	15	8	8	2				
Number of achievements indirectly impacting objective		11	15	13	11	14	17	20	8	10				
Number of achievements with minimal impact on objective		1	9	2	2	12	1	5	17	21				

Key:

Achievement **directly impacts** objective

Achievement **indirectly impacts** objective

Achievement has **minimal impact** on objective

	G1 World Standard					G2 Expert Advisory Role		G3 Governance & Development		Direct Impact on number of objectives	Indirect Impact on number of objectives	Minimal Impact on number of objectives	Activity Impact Index =direct*9 + indirect*3 + minimal*1
	O1.1 Quality	O1.2 New user needs	O1.3 IGS/GNSS Integration	O1.4 GNSS Standards	O1.5 Customer footprint	O2.1 Expertise	O2.2 Policy Advisory role	O3.1 Best practices	O3.2 Funding				
Ongoing achievements													
Bi annual GB meetings/business meetings/monthly GB teleconferences										7	2	0	69
Maintain CBIS/Website										4	5	0	51
Introduce new products										4	4	1	49
International Committee on GNSS meetings/committee meetings										4	4	1	49
Update major software used in IGS product development										4	3	2	47
Update IGS combination software										4	3	2	47
Continued quality monitoring and improvement of core products										3	4	2	41
Developing understanding of GPS/GLONASSS intersystem biases										3	4	2	41
Update Infrastructure to accommodate new applications/maintain reference frame stability										3	4	2	41
Data Centers continue to accommodate new data types										3	4	2	41
Maintain IGS Site Guidelines										3	4	2	41
Biennial IAG Meetings										2	6	1	37
National PNT Advisory Committee participation										2	5	2	35
SIP Process track progress against Strategic Plan Goals										2	4	3	33
IERS Directing Board participation										2	4	3	33
GGOS Directing Board participation										2	4	3	33
Ongoing GB recruitment and elections/Chairman election										2	3	4	31
Ongoing IGS Associate review										2	3	4	31
Annual Strategic Implementation Plan/Scoring										1	7	1	31
FIG meetings										1	6	2	29
WDS meetings										1	6	2	29
AGU/EGU meetings										1	6	2	29
IAG meetings										1	6	2	29
Periodic Reports/Progress Reports										1	4	4	25
Sum										62	105	49	
Number of achievements directly impacting objective	8	7	10	4	10	7	5	9	2				
Number of achievements indirectly impacting objective	6	12	8	17	10	16	18	8	10				
Number of achievements with minimal impact on objective	10	5	6	3	4	1	1	7	12				

Appendix 3

Component Impact Analysis

Key:

Achievement **directly** impacts objective

Achievement **indirectly** impacts objective

Achievement has **minimal** impact on objective

	G1 World Standard					G2 Expert Advisory Role		G3 Governance & Development		Direct Impact on number of objectives	Indirect Impact on number of objectives	Minimal Impact on number of objectives	Activity Impact Index =direct*9 + indirect*3 + minimal*1
	O1.1 Quality	O1.2 New user needs	O1.3 IGS/GNSS Integration	O1.4 GNSS Standards	O1.5 Customer footprint	O2.1 Expertise	O2.2 Policy Advisory role	O3.1 Best practices	O3.2 Funding				
IGS Components													
Governing Board/Executive Committee										5	4	0	57
Central Bureau/IGS Institute/CBIS										5	4	0	57
Elections Committee										1	3	5	23
IGS Associates Committee										1	3	5	23
Infrastructure Committee										4	3	2	47
Data Centers										1	5	3	27
Network Coordination/Stations										4	4	1	49
Analysis Coordinator/Analysis Centers										4	4	1	49
Reference frame Coordinator/ WG										2	4	3	33
Timing and Clock Products WG										1	4	4	25
Troposphere WG										1	5	3	27
Ionosphere WG										3	3	3	39
MultiGNSS WG/M-GEX Project										7	1	1	67
Antenna WG										3	2	4	37
Real-time WG/Project										4	4	1	49
Space Vehicle Orbit Dynamics WG										2	2	5	29
RINEX WG										3	3	3	39
Bias and Calibration WG										3	3	3	39
Associate Members										1	8	0	33
Sum										55	69	47	
Number of components directly impacting objective	13	5	9	8	4	6	3	5	2				
Number of components indirectly impacting objective	4	8	8	9	7	13	12	3	5				
Number of components with minimal impact on objective	2	6	2	2	8	0	4	11	12				
Total													
Number of achievements directly impacting objective	32	21	37	32	21	28	16	22	6				
Number of achievements indirectly impacting objective	21	35	29	37	31	46	50	19	25				
Number of achievements with minimal impact on objective	13	20	10	7	24	2	10	35	45				
Total										225	293	166	

