Bureau of Networks and Observations Implementation Plan for 2020 – 2022

Version 7a

1.0 IMPLEMENTATION OVERVIEW

1.1 Introduction

The Bureau of Networks and Observations (BN&O) works with the IAG Services to address requirements set by the GGOS Science Committee. The Bureau focuses primarily on the infrastructure needed to maintain the International Terrestrial Reference Frame (ITRF) and the International Celestial Reference Frame (ICRF), in a sustainable way, over the long-term (~20 years), while at the same time, addressing other scientific applications identified as important to GGOS and the IAG. In particular, BN&O supports the current efforts oriented to the establishment of the International Height Reference Frame (IHRF) and the International Gravity Reference Frame (IGRF). The infrastructure currently includes the space geodetic network of co-located instruments (VLBI, SLR, GNSS, DORIS) and other instruments or observations (gravity field measurements, reference clocks, tide gauges, etc.) that may be added to enhance the data products. In the near future, the description of the infrastructure will be extended to include core stations of the IHRF and IGRF.

Standing Committees and Joint Working Groups including the Standing Committee on Performance Simulations & Architectural Trade-Offs (PLATO); the Standing Committee on Satellite Missions, the IERS Working Group on Survey Ties and Co-location, and the Standing Committee on Data and Information are included in the Bureau in recognition of their synergistic role with Bureau activities The Bureau advocates for implementation of core and co-location network sites to satisfy GGOS requirements, monitors the present state of the networks and projects future status, and supports and encourages maintenance and improvement in the infrastructure critical for the development of data products essential to GGOS.

The Bureau, originally established as the Bureau of Networks and Communications in 2003), works to exploit synergistic opportunities to better integrate or co-locate with the infrastructure and communications networks of the many other Earth observation disciplines organized under GEOSS, and to work with current and perspective organization to help improve the network capability. Aside from the geometric services the IGS (Dow, J. et al., 2009), the IVS (Schuh, H. et al, 2012; Behrend, D., 2013), the ILRS (Pearlman, M. et al., 2002), the IDS (Willis, P. et al., 2016); the IGFS (Wziontek, H. et al. 2011) and the PSMSL (Simon, J. et al, 2013) are now integral components of the Bureau.

Efforts are underway by GGOS to integrate these other services and techniques into the GGOS network to enhance geodetic products.

The Bureau of Networks and Observations provides a means of greater coordination among the services and the supporting entities and provides a conduit for discussion and information to GGOS on policy and decision-making. The role of the Bureau will be based on the requirements set by GGOS and the IAG and its integration into the GGRF.

1.2 Goals and Objectives

The primary goal of the Bureau is to work with the Services and the funding agencies to advocate for the enhanced networks of sufficient global distribution and measurement capability to address the Earth science and societal benefit requirements set by GGOS. Satisfying this goal requires development of a strategy to design, integrate, implement and maintain the core geodetic network of co-located instruments and supporting infrastructure in a sustainable way. At the base of GGOS are the sensors and the observatories situated around the world providing the timely, precise, and fundamental data essential for creating geodetic products. Primary emphasis must be placed on sustaining the infrastructure needed to maintain the evolving terrestrial and celestial reference frames, while at the same time ensuring the broader support of the scientific applications of the collected data. Synergistic opportunities should be exploited to better integrate and co-locate with the infrastructure and communications networks of the many other Earth observation disciplines organized under GEOSS. Furthermore, additional measurements, such as those from the gravity field and from tide gauge networks, must be included.

Although the Bureau will get its primary direction from the GGOS Science Council and the Executive Committee, the Bureau and the services must also recognize scientific and societal benefits and important synergies that will accrue through connection with the other entities.

The Bureau will work with the UN GGIM Subcommittee on Geodesy in its mission to develop a sustainable Global Geodetic Reference Frame (GGRF). The documents listed below give an overview of the goals of the Committee.

- Position Paper on Sustaining the Global Geodetic Reference Frame (Committee on Geodesy)
- Concept Paper on Establishing a Global Centre of Excellence (Committee on Geodesy)
- Global Geodetic Centre of Excellence (GGCE) for the United Nations Global Geospatial Information Management – IN-GGIM. (Federal Government of Germany)

From the Subcommittee work packages, the Bureau sees its main role involved in Sub ID INF.2, with particular stress on "Communicate plans for IAG services to be used to modernize/improve geodetic infrastructure", and advocate for the implementation of the improved infrastructure (network).

1. This activity should start with the performance of the current network stations and their contribution to the data products. The anticipated capability from new stations underway and planned, and from current stations being upgraded would be added. Then using simulation techniques, the added capability needed to meet the ITRF requirement would be estimated and commensurate enhanced network configurations studied, along with other steps that would enhance the projected capability (Co-location in space, separated stations connected by redundant GNSS measurements from a continuously operating GNSS network, etc.). General location of stations that will be required have been advanced in many publications already (e.g. Core Sites in Africa, Latin America, and Oceana). We are hoping that the UN GGIM Committee on Geodesy will help us make proper inroads.

The Roles of the Bureau are to:

1. In collaboration with the UN GGIM and the Services formulate a network development plan to address the GGOS requirements;
2. Advocate for the expansion and upgrade of the space geodesy network for the maintenance and improvement of the reference frame and other GGOS priorities; Main focus will be on the Reference Frame; but the other applications need to be accommodated;
3. Encourage partnerships to build and upgrade network infrastructure
4. Organize and expand the GGOS affiliated network;
5. Monitor network status; project network evolution based on input from the Services and the sponsors; estimate performance capability 5 and 10 years ahead;
6. Conduct simulation studies and analyses to assess impact on reference frame products of: network configuration, system performance, technique and technology mix, co-location conditions, site ties, and network trade of options (PLATO);
7. Develop Metadata Systems for a wide range of users including GGOS; near term strategy for data products (Carey Noll at GSFC) and a more comprehensive longer-term plan for an all-inclusive system (Committee on Data and Information);
8. Enhance and improve knowledge of local tie surveys through applied field practice, research, and dissemination of materials developed (IAG Joint Working Group (w/ IERS) 1.2.1)
9. Advocate, coordinate, and exchange information with satellite missions as part of the GGOS space infrastructure, for a better ground-based network response to mission requirements and space-segment adequacy for the realization of the GGOS goals (Committee on Missions)

10. Provide the opportunity for representatives from the Services and the Standing Committees to meet and share progress and plans; discuss issues of common interest; meetings at EGU, AGU, GGOS Days, etc.;
11. Talks and posters on the Bureau at EGU, AGU, JPGU-AGU, AOGS meetings, etc.;
12. Letters/documentation to support stations, current/ new missions, and analysis centers;

1.3 Bureau of Networks and Observations Authority, Governance Structure, Management Structure, and Implementation Approach

1.3.1 Authority

The Bureau is a "consortium of the willing"; its only authority is that recognized by its members.

The Bureau is a consortium of representatives of the IAG Services, Commissions, Standing Committees and Participating Working Groups with a common goal of guiding the design, evolution and implementation of the observation-gathering networks. The Bureau will maintain a liaison with the GGOS Focus Areas and include them in Bureau activities. The Bureau is self-managed, following the guidelines, policies, and procedures put in place by the GGOS Coordinating Board. The Bureau works with the services and committees and working groups to formulate their tasks that will support these policies and procedures, implementing reporting procedures/plans in a timely yet reasonable manner to have direct impact on the Bureau goals. The Bureau is essentially a "consortium of the willing" benefitting from members' implementation plans to satisfy programs enacted by their parent organizations, which are likely, a component of GGOS. In many cases the Bureau task will be advocating, promoting, and/or measuring progress.

Elements within the Bureau will need to interact with entities outside the Bureau; some of these are spelled out in the working group briefs in Appendix 4.1. If direct contact does not prove fruitful then the Bureau and its committees will work through the Coordinating Board (CB).

1.3.2 Membership

GGOS and the Bureau will benefit significantly from expanding its membership both technically and geographically. In particular, we encourage the promotion of GGOS Regional Affiliates as our Japanese colleagues have done, and by expanding participating partnerships.

Table 1.2-1: Bureau of Networks and Observations Goals and Objectives Mapping. The table identifies the primary (✓✓) and secondary (✓) Goals and Objectives that the Bureau of Networks and Observations will be supporting to meet the outcomes stated in the GGOS strategic pan. Primary goals and objectives are those that are aligned with the charter of the GGOS Entity in question and are not likely to be realized without its involvement. Secondary goals and objectives are those that the given GGOS Entity can support as part of its charter.

	Goal 1 – Geodetic Information and Expertise			Goal 2 – Global Geodetic Infrastructure		Goal 3 - Services, Standardization, and Support		Goal 4 - Communication, Education, and Outreach	
	Objective 1-1 – Understand societal and scientific needs and deficiencies	*Objective 1-2 – Position GGOS as the primary source for geodetic information and expertise*	*Objective 1-3 – Connect with the larger scientific community and integrate with other Earth observing*	*Objective 2-1 – Support and advocacy for infrastructure and associated elements*	*Objective 2-2 – Lead efforts for the integration of various ground observation networks within the GGOS network*	*Objective 3-1 – Standardization*	*Objective 3-2 – Coordination and Development of IAG Services*	*Objective 4-1 – Establish a Strong Internet/Online Presence*	*Objective 4-2 – Outreach to the Technical Community and General Society*
Coordinating Board	✓✓	✓✓	✓	✓	✓	✓	✓	✓	✓
Consortium	✓	✓	✓✓	✓	✓	✓	✓✓		✓
Coordinating Office	✓	✓	✓	✓	✓	✓	✓	✓✓	✓✓
Bureau of N&O			✓	✓✓	✓✓	✓	✓		
Bureau of P&S	✓	✓	✓	✓		✓✓	✓✓		
Science Panel	✓✓	✓	✓✓				✓		✓

The focus of the Bureau has been primarily on the geodetic networks and the functions that support them, and in some cases the disposition of their products. The IGFS has been working with the Bureau to define measurement and station configuration requirements for the IHRF and the IGRF. It is assumed that best use will be made of the network core and co-location sites. The PSMSL has been working with the IGS on the co-location of IGS instruments with operating tide gauges; discussions are also underway with DORIS. Once these are formulated, the Bureau will work with the Bureau of Products and Standards (BP&S), the themes, and focus areas to identify and quantify measurement requirements and help integrate these requirements into the network. A draft of these requirements will be included in the next version of the CORE and Co-location Site Requirements Document. It is assumed that the best use of the network Core and co-locations sits.

1.3.2 Governance Structure

Not Applicable

1.3.3 Management Structure

ALLOCATION AND DISTRIBUTION OF RESOURCES

All resources to support the Bureau will be provided by its members; we do not anticipate that any external support funds will be available. As such, the resources required to run the Bureau will be the personnel, travel, and other services provided by its participants through their support agencies/institutions. See Table 1.3-1.

The IGS, IVS, ILRS, IDS, IGFS, PSMSL, and the IERS are represented in the Bureau. The IAG services and the standing committees chose their member representatives to the Bureau. Some rules may be formulated for succession.

The Standing Committees and Working Groups within the Bureau have formulated work plans in concert with the Bureau that address key issues for GGOS.

Table 1.3-1: BN&O Resources.

Position	Resource	Entity Contributing
Director	Mike Pearlman	CfA (USA)
Deputy Director	TBD	TBD
Secretary	TBD	TBD
Analysis Specialist	Erricos Pavlis	UMBC (USA)
IVS Service Representatives	Hayo Hase Dirk Behrend	BKG (Germany) NASA (USA)
ILRS Service Representatives	Toshi Otsubo Jean-Marie Torre	HIT-U(Japan) OCA (France)
IGS Service Representatives	Allison Craddock Michael Moore	JPL (USA) GA (Australia)
IDS Service Representatives	Jérôme Saunier Guilhem Moreaux	IGN (France) CLS France)
IGFS Service Representatives	Riccardo Barzaghi George Vergos	PM (Italy) UT (Greece)
PSMSL Service Representatives	Elizabeth Bradshaw Lesley Rickards	BODC (UK) BODC (UK)
IERS Representatives	Ryan Hippenstiel	NOAA/NGS
Standing Committee on Performance Simulations & Architectural Trade-Offs (PLATO) – joint with IAG Commission 1	Daniela Thaller Benjamin Maennel	BKG (Germany) GFZ (Germany)
Standing Committee on Data and Information	Nicholas Brown TBD	GA (Australia) NASA (USA)
Standing Committee on Satellite Missions	Roland Pail C.K. Shum	TUM (Germany) OSU (USA)
IERS Working Group on Survey Ties and Co-Location	Ryan Hippenstiel	NOAA (USA)

OVERSEEING AND COORDINATING THE DAY-TO-DAY OPERATIONS

The Bureau will work with each entity to develop and update a task plan with a projected schedule.

The Bureau does not oversee or coordinate the day-to-day activities of the services. The services are their own entities within the IAG, with representation in the Bureau who help guide the Bureau in its fulfillment of GGOS requirements. Day-to-day activities within the purview of the Bureau will be coordinated and overseen by the individual entities, with periodic reviews by the Bureau, working with the entity and recommending remedial action if necessary.

REPORTING OF TECHNICAL AND/OR SCIENTIFIC PROGRESS AGAINST SCHEDULE

All services and standing committee/working groups will give oral and/or written reports periodically, as required, on progress, adherence to the task plan, forced deviations, and changes in circumstances and plans. Committees and Working Groups will have the opportunity to give a report at the Bureau meetings to be held during EGU, AGU and possible at a third opportunity at roughly mid-year (meeting or teleconference). All entities must report at the Bureau meeting at EGU and must provide a written summary report for the annual GGOS Days meeting. The Bureau will give summary reports at GGOS meetings and on the BN&O webpage on the GGOS website https://ggos.org/

DESCRIBE ANY CONFIGURATION MANAGEMENT REQUIRED FOR MANAGEMENT

Each of the services and standing committee/working groups will establish a page or a link (to a page elsewhere) on the GGOS Bureau section of the GGOS website to archive documents, and post plans and progress reports. The Bureau will provide summary reports and estimates of impact on schedule.

Table 1.3-2: Bureau of Networks and Observations Plan. The table identifies the communications requirements of the BN&O

Communication Type	Purpose	Medium	Frequency	Audience	Owner	Deliverables
GGOS BN&O report at the GGOS EC meetings	Report in BN&O status, progress, issues, and action items	Video conference or telecon	Monthly or as decided by the EC	EC members	EC	Oral report
GGOS BN&O report at the GGOS CB and Consortium Meetings	Report in BN&O status, progress, and issues; other reports as requested by the CB	Face-to-face; may include video conferencing	Twice per year (EGU, AGU); additional meetings as decided by the CB	CB members and Consortium Members	CB	BN&O Presentations material and other material as requested by the CB and Consortium
Bureau and entity report at GGOS Days	Report in BN&O and entity status, progress, issues, and action items	BN&O: Face-to-face and written; Entity Reports written	Annually	Invitees to GGOS Days	EC	Written Bureau and Entity reports
Component Reports at the GGOS BN&O Meetings; Summary meeting Report	Bureau and entity Status Review and issues	Face-to-Face; may include video conferencing	AGU, EGU and any other time set by the Bureau	Bureau members, invitees, and interested parties.	BN&O	Before: Agenda After: Presentation material posted on the website; meeting notes; action items.
BN&O Committee and Participating Working Group Meetings	Review progress and plan forward	Face to Face or telecon as the discretion of the entity	Annually of at the discretion of the entity	Entity members and interested parties.	Entity	Summary report and status of tasks
Focused meeting	Review status on specific topics	Oral and written	At the discretion of the Bureau	Bureau and entity members involved	BN&O and involved entities	Oral and written report

1.3.4 Implementation Approach

The Bureau is a consortium of IAG service representatives and participating standing committees/working groups. Two members of each Bureau entity are members of the Bureau leadership; thus, each entity participates in the Bureau discussions. The Bureau leadership will encourage members of each entity to attend and participate in functions/meetings/workshops of other entities. This overall structure will be implemented to provide close interaction among the entities to enhance cross-fertilization and communication.

The Bureau will define the near- and long-term objectives to support GGOS goals.

The Bureau will coordinate closely with the Bureau of Products and Standards (BP&S) and look to the BP&S, CB, and the EC for guidance in setting network requirements to address new data products (themes, new focus areas, etc.) and to help the Bureau to formulate its recommendations and options.

The Bureau and its services may interact with some or all of the agencies and organizations that participate or will participate in the network or are key interface points for the missions.

The Bureau does not capital decisions; in concert, the Services and the sponsors might decide to make such decisions.

1.4 Stakeholder Definition

The network data are the basis for the development of the reference frame and many of the other data products that GGOS will facilitate. As such, GGOS is the main internal stakeholder along with its internal entities the Bureau for Products and Standards, the GGOS Portal, etc. See table 1.4-1 below

The data from the GGOS network are the basis for the reference frame, precision orbit determination, precise station positioning, Earth rotation, and all of the other data products to be formed, soon to include including gravity field and tide gauges. External stakeholders will include the IAG services, IERS, and other scientific organizations and research institutions. It will include the broad range of the external data and data product users including those working in navigation, civil engineering, surveying and mapping, precision timing applications, precision orbit determination, altimetry, monitoring environment, and global change phenomena, etc. The BN&O will work with the IGFS and the PSMSL/TIGA to advocate and promote network requirements of these communities in support of GGOS-endorsed data products.

Stakeholder advocacy will be done at the services, the Bureaus, and GGOS level.

The advocacy strategy seems to be a general GGOS task and shall be discussed within GGOS.

Table 1.4-1 summarizes the advocacy strategy for the identified internal and external stakeholders of the GGOS Bureau of Networks and Observations

2.0 GGOS BUREAU OF NETWORKS AND OBSERVATIONS BASELINES

PROJECT BASELINES CONSIST OF A SET OF REQUIREMENTS, A SCHEDULE, AND TECHNICAL OR SCIENTIFIC CONTENT THAT FORMS THE FOUNDATION FOR THE GGOS ENTITY. BASELINES ALSO DETAIL THE EXECUTION AND REPORTING THAT IS DONE AS PART OF GGOS GOVERNANCE PROCESSES AND PERFORMANCE ASSESSMENTS.

The role of the Bureau is to advocate for the implementation of the ground network of sufficient global distribution and measurement performance capability to address the Earth science and societal benefit requirements set by GGOS. The Bureau will monitor progress in the development of the networks, project network configuration based on information provided by the Services, make recommendations based on analysis and simulations, and distribute information to the community. Through the IERS Working Group for Site Survey and Co-location it will work to improve site tie participation including more frequent measurements and use of improved technology.

Through the Standing Committee on Data and Information the Bureau will work on the development and implementation of a GGOS metadata system.

The main focus of the Bureau is presently the reference frame and the evolution of the global geodetic networks over time, but work is underway by Bureau and the IGFS and the PSMSL to better define their role and position within the network, their data products and the measurement requirements, and their contribution the reference frame. As the network improves, there should be commensurate steps in the improvement of the reference frame. The Bureau will regularly report at the CB meeting and public meetings on the evolution and plans for the network. Since the implementation of the full core sites network capability will be very costly and take many years to achieve, near-term compromises in network design and capability will be required in order to accommodate realistic constraints. The Bureau will encourage the implementation and upgrade of co-location sites to augment the core network, and the inclusion of new techniques to allow the network to support other data products.

As additional data products are developed and formalized, they will place additional requirements on the network.

Table 1.4-1: BN&O Stakeholders and Advocacy Strategies

STAKEHOLDERS	ADVOCACY STRATEGIES
INTERNAL STAKEHOLDERS	
GGOS Coordinating Board, GGOS Consortium, other GGOS entities including the GGOS Bureau of Products and Standards, GGOS Portal, Outreach, etc.	As the observing system of the IAG, GGOS serves a unique and critically important combination of roles centering upon advocacy, integration, and international relations. The IAG relies upon GGOS and the GGOS BN&O to advocate for improvements in the ground-based geodetic infrastructure of GNSS and DORIS reference stations, VLBI and SLR space geodetic stations, and gravity observatories; it also supports the development of new satellite missions for altimetry, gravity mapping, and Earth observation. Overall, the Bureau promotes the importance of modern geodesy for addressing the needs of science and society for stable reference frames. *Advocacy strategies will include monthly telephone conferences with the Executive Committee and the Coordinating Office, biannual (or more frequent) meetings with the GGOS Coordinating Board and Consortium, and written reports as required to report progress and issues to help support the GGOS role in CEOS, GEO, GIAC, and UN-GGIM and other international organizations*
IAG Network, etc. Services	GGOS BN&O works with the pertinent IAG services (at the moment the IGS, IVS, ILRS, IDS, IGFS, and PSMSL) to advocate for and support the maintenance and upgrade of the network infrastructure necessary for monitoring the Earth system and for global change research. *Each of the pertinent services has representation in the BN&O. Advocacy strategies will include frequent email and telephone conferences with these service representatives, a minimum of twice-yearly Bureau meetings, as well as face-to-face meetings at major conferences and/or workshops (approximately two to three times per year) to discuss progress and issues.*
IERS	The IERS develops the final reference frame products and thus relies on the BN&O advocating role, coordination with the service networks, and status and network capability projections activities. The IERS Working Group on Survey Ties and Co-location supports BN&O activities. *Advocacy strategies will include offering a position in the Bureau for a representative from the IERS, frequent email and telephone conferences with IERS personnel, a minimum of twice-yearly Bureau meetings, as well as face-to-face meetings at major conferences and/or workshops (approximately two to three times per year) to discuss progress and issues.*

EXTERNAL STAKEHOLDERS	
OUTSIDE ORGANIZATIONS	Mapping agencies, space agencies, universities and research groups, etc. who are the owners of the geodetic infrastructure

2.1 Requirements Baseline

LIST OR REFERENCE ANY REQUIREMENTS LEVIED ON THE BUREAU OF NETWORKS AND OBSERVATIONS THE BY THE PARENT GGOS ENTITY, SUCH AS THE COORDINATING BOARD OR IAG; AND DISCUSS HOW THESE ARE FLOWED DOWN TO LOWER LEVELS, SUCH AS GGOS OR IAG SERVICES WORKING GROUPS. SUMMARIZE CORRESPONDING ALLOCATION PROCESSES. REFERENCE REQUIREMENTS DOCUMENTS USED BY THE BUREAU OF NETWORKS AND OBSERVATIONS, E.G., GLOBAL OBSERVING SYSTEM, MEETING THE REQUIREMENTS OF A GLOBAL SOCIETY... (SECTION 7.8, OPERATIONAL SPECIFICATIONS FOR GGOS). USE TABLE 2.1-1.

2.1.1 Geometric Space Geodesy Network

The reference frame baseline requirements are levied by the GGOS 2020 document. The most stringent requirement comes from sea level rise:

- Accuracy of 1 mm, and stability at 0.1 mm/yr., a factor of ~5 beyond current capability;
- Accessibility: 24 hours/day; worldwide;
- The space segment is currently defined by LAGEOS-1 and -2, LARES, GNSS, DORIS, and the quasars;
- The ground segment is defined by a global distributed network of "modern technology", co-located SLR, VLBI, GNSS, DORIS stations and other ground-based measurements (e.g., gravimeters, tide gauges, etc.), locally tied together with accurate site ties;
- A dense network of GNSS ground stations to distribute the reference frame globally to the users;

Studies performed by Erricos Pavlis/UMBC have translated this requirement into a network-size specification to define and maintain the reference frame;

- ~ 32 globally distributed SLR, well positioned, new technology sites;
- ~ 24 globally distributed VLBI, well positioned, new technology (VGOS) sites, co-located with SLR;
- ~ 16 of these co-location sites must track GNSS satellites with SLR to calibrate the GNSS orbits, which are used to distribute the reference frame.

Recognizing that many sites will not be at ideal locations nor have ideal conditions, core site deployment will occur over many years, and we will have a mix of new and legacy technologies for many years; co-location sites (non-core sites) will continue to play a vital role in our data products and that the quality of our output will be the product of network core sites, co-location sites, mix of technologies, adherence to proper operational and engineering procedures, and making best use of the data once it leaves the field.

The “heavy lifting” in network deployment and upgrade will be done by the National and Research Institutes, Space Agencies, Universities, and other entities that provide the funding and infrastructure. We expect that these entities will work with the Services and the Bureau to take advantage of existing experience and expertise, and implement and upgrade to address IAG/GGOS requirements. The GGOS BN&O will advocate for implementation of the global space geodesy network of sufficient capability to achieve data products essential for GGOS and will provide a multi-technique community for the services to work and plan together. The BN&O will monitor and project the status and evolution of the space geodesy network and project network performance capability to help guide the activities.

2.1.2 Global Gravity Reference Network

The gravity reference system in use is the International Gravity Standardization Net 1971 (IGSN71) (Morelli et al. 1974). It was stablished in the 1960s and 1970s by means of relative gravity measurements based on a few absolute gravity stations and presents an uncertainty at the level of 10^{-6} m s^{-2} . This uncertainty level is insufficient to meet the requirements imposed by the measurement accuracy of 5 to 10 × 10^{-8} m s^{-2} achievable by modern gravimeters and needed to monitor and understand changes within the Earth System. In agreement with the IAG Resolution No. 2 (2015) “Establishment of a Global Absolute Gravity Reference System” (Drewes et al., 2016), an essential task for the near future is the implementation of the International Gravity Reference Frame (IGRF) as the realization of the International Gravity Reference System (IGRS), see Wziontek et al., (2021). The IGRS is defined by the instantaneous acceleration of free-fall, expressed in the International System of Units (SI) and a set of conventional corrections for time-invariant and time-dependent components of gravity effects. The IGRF is given by a global set of stations where reliable absolute gravity values with a relative accuracy of 10^{-8} and better are provided. According to Wziontek et al., (2021), the main infrastructure of the IGRF is formed by:

- Reference stations to ensure a long-term stable absolute gravity reference. These stations should be equipped with a continuously operating superconducting gravimeter in combination with repeated absolute gravity observations or a continuously operating absolute quantum gravimeter. If a continuous monitoring is not possible, repeated absolute gravity observations are needed. Stations of the International Geodynamics and Earth Tide Service (IGETS) (Boy et al. 2020) with long-term superconducting gravimeter records should become an essential part of the IGRF.
- Comparison stations are reference stations with extended facilities to check the compatibility of instruments, based either on continuous gravity monitoring or by simultaneous measurements of at least two absolute gravimeters.
- Core stations to ensure a link to the ITRF. They should be co-located with GGOS core sites and further ITRF stations where at least one space geodetic technique is established. In accordance with the GGOS requirements for core sites, it is recommended to continuously monitor temporal gravity variations and to repeat absolute gravity observations at all GGOS core sites.

In order to guarantee sustainability of the gravity reference frame, all stations of the IGRF need to be indicated by a permanent marker. All measurements at these stations should be documented and archived in the IAG absolute gravity database (AGrav) operated by BGI (Bureau Gravimétrique International) and IGETS for static and time variable measurements, respectively. By this, the basis for the further development of compatible infrastructure on the national level is provided.

Based on the advances and challenges described by Wziontek et al., (2021), the Bureau will work with the IGFS, BGI, IGETS and the Bureau of Products and Standards to support the implementation of the IGRF. An immediate step is to include the IGRF station requirements in the documentation supporting the description of GGOS core sites (Appleby et al., 2015). The Bureau will also support the activities of the working group "On the realization of the International Gravity Reference Frame" chaired by H. Wziontek (Germany) and S. Bonvalot (France) for the term 2019 – 2023. The main objective of this working group is to promote the development of an adequate infrastructure based on absolute gravity measurements supported by international and national institutions, agencies and governmental bodies responsible for the geodetic reference frames.

2.1.3 Global Unified Physical Height Reference Network

The IAG introduced in 2015 the International Height Reference System (IHRS) as the conventional reference for the determination of gravity field-related heights (see IAG Resolution No. 1 (2015) in Drewes et al., 2016). The IHRS is defined in terms of potential quantities (Ihde et al., 2017): the vertical coordinates are geopotential numbers [C(P) = W0 – W(P)] referring to an equipotential surface of Earth's gravity field realized by the IAG conventional value $W_0 = 62\ 636\ 853.4\ m^2s^{-2}$. The spatial reference of the position P for the potential W(P) = W(**X**) is given by coordinates **X**, d**X**/dt of the ITRS/ITRF. Thus, IHRS essentially materializes the combination of a geometric component given by the coordinate vector **X** in the ITRS/ITRF and a physical component given by the determination of potential values W at **X**. The realization of the IHRS is the International Height Reference Frame (IHRF): a global reference network with regional and national densifications, whose geopotential numbers referring to the conventional potential W_0 are known. To be in agreement with the certainty of the geometric coordinates, the accuracy of the IHRF geopotential numbers and their variation with time should be at least $\pm 3\times10^{-2}\ m^2s^{-2}$ (equivalent to $\approx \pm 3$ mm in height) and $\pm 3\times10^{-3}\ m^2s^{-2}a^{-1}$ ($\approx \pm 0.3\ mm\ a^{-1}$), respectively (see Ihde et al., 2017). However, the present achievable accuracy is some orders lower (from $\pm 10\times10^{-2}\ m^2s^{-2}$ to $\pm 100\times10^{-2}\ m^2s^{-2}$). In this frame, current efforts concentrate on (Sánchez and Barzaghi, 2020): (i) designing a preliminary reference network for the IHRF; (ii) studying strategies for the determination of precise potential values W(P); and (iii) identifying/outlining the standards and conventions required to establish an IHRF consistent with the IHRS definition.

According to Sánchez et al. (2021), the reference network for the IHRF should comprise (i) a core network to ensure perdurability and long-term stability of the reference frame, and (ii) regional and national densifications to provide local accessibility to the global IHRF. This reference network is to be collocated with:

- fundamental geodetic observatories (GGOS core sites) to allow the connection between **X**, W, **g** and reference clocks,
- continuously operating GNSS reference stations to detect deformations of the reference frame,
- geometric reference stations of different densification levels (ITRF and regional reference frames) to provide access to the IHRF at regional and national levels,
- reference tide gauges and national vertical networks to facilitate the vertical datum unification within the IHRS, and
- reference stations of the IGRS/IGRF (Wziontek et al., 2021).

A main requirement is the availability of surface gravity data around the IHRF stations to ensure a high reliability in the determination of the reference potential values W(P). Currently, the GGOS Focus Area Unified Height System and its working group "Implementation of the International Height Reference Frame (IHRF)", chaired by L. Sánchez (Germany) and R. Barzaghi (Italy) are evaluating the quality of potential values obtained with the existing resources (surface gravity data, global gravity models, topography models, regional geoid models, etc.) at GGOS core sites and ITRF reference stations in order to establish if additional gravity surveys around these stations are needed. A further goal of this working group is to identify the elements required to install a scientific operational infrastructure for the IHRS/IHRF, considering the existing gravity field-related IAG services and highlighting missing elements and interfaces to be established within the IGFS as natural home of the IHRS/IHRF.

Based on the advances and challenges described by Sánchez et al., (2021), the BN&O will work with the GGOS Focus Area Unified Height System, the IGFS, the IAG Commission 2, and the Bureau of Products and Standards to support the implementation of the IHRF. Immediate steps are to include the IHRF station requirements in the description of the GGOS core sites (Appleby et al., 2015) and to support the design of the new IGFS element to maintain and provide the IHRS/IHRF.

1.4 Tide Gauge Network (PSMSL)

Tide gauge data are being used to develop ocean circulation, tidal and storm surge models; monitor tsunamis, storm surges, and long-term sea-level changes; and help validate satellite ocean surface altimeters. The two main issues with tide gauge networks are the large number of gauges that do not have local GNSS (or DORIS) receivers for accurate and continuous geo-location in the geodetic reference frame and the gaps over large coastal and oceanic expanses due to either inoperative units or lack of instrumentation entirely.

The IGS is working with PSMSL to improve the co-location of the GNSS with the tide gauges. They are encouraging the geodetic community to properly deploy GNSS receivers in close proximity to existing tide gauges, to make the resulting tide gauge and GNSS data publicly available with in international data archives sanctioned by GLOSS, IGS, GGOS, etc., to encourage the establishment of geodetic ties between the GNSS receivers and tide gauges, to advocate for more absolute gravity sites at tide gauges, and to advocate for placement of tide gauges in regions void of such systems but of great scientific and societal interest. In accomplishing these tasks, we recognize that oceanographic, as well as geodetic, entities are involved (i.e., IOC/GLOSS, GCOS, or GOOS).

A similar effort has long been made by IDS taking all opportunity to co-locate new DORIS stations with tide-gauges. Half of the DORIS network is already co-located with tide-gauge. . The Bureau will address this need at different institutional and political levels and provide support to initiatives to improve the network situation.

The Service is also planning to address three additional goals:

- 1 year - We will update the PSMSL website to link to co-located GGOS services at tide gauges
- 1 year - PSMSL will update the ellipsoidal links available on our website (https://www.psmsl.org/data/obtaining/ellipsoidal_links.php) to a show range of GNSS solutions
- 3 year - We will investigate using Interferometric Synthetic Aperture Radar (InSAR) to establish wide areas of land movement, for the development of localized flood risk products

Table 2.1-1: GGOS BN&O Specifications and Requirements Allocation

Requirement Reference	Requirement and Interpretation	GGOS Allocation	IAG Service (or other entity) Allocation
GGOS-Ops-1	Operate global networks of geodetic reference stations, gravimeters; support the long-term operation of tide gauges relevant for GGOS.	BN&O	IAG services
GGOS-Ops-2	Operate a global sub-network of core reference stations at which the techniques are co-located.	BN&O	IAG services
GGOS-Ops-3	Determine the survey ties between the co-located techniques.	BN&O/IERS WG on ST&C	IAG services and space geodesy sites; individual institutions operating GGOS sites; IERS
GGOS-Ops-4	Process all geometric and gravimetric observations with an accuracy and consistency of at least 1 ppb.	BN&O	IAG services

2.2 Schedule Baseline

The scheduled activities for each of the entities within the BNO are described in the sections below. The activity areas are summarized in Table 2.2-1 because they are too extensive for the table. The activity areas are divided into four sections: Communications and Coordination Activities; Tasks on network planning and evaluation, Task areas of the Networks/Services, and Tasks areas of the Standing Committees/Working Groups.

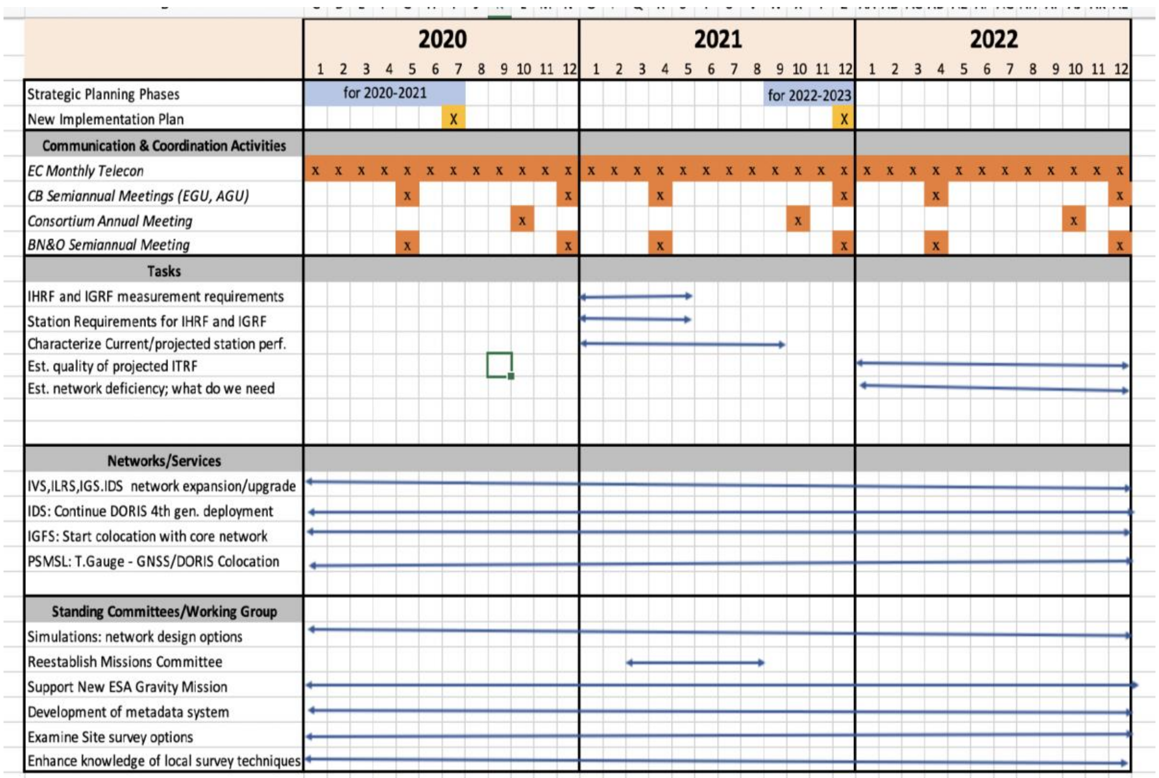

Fig. 2.2.1: Overview and schedule of BNO activities

2.2.1 Bureau of Networks and Observations

Overview and Schedule of BNO activities

All of the contributing IAG services will focus on their respective network coordination, data acquisition, and data analysis to generate products for science and societal needs articulated by GGOS. The services will constantly strive to improve the robustness and quality of their data and the results through improved procedures, technologies, and modeling. The services and Committees give brief summary reports as a part of the Bureau meeting; these are summarized in the Bureau reports.

1. Complete the ITRF2020 and characterize its performance in terms of accuracy and spatial and temporal coverage; (IERS/Altamimi);

2. Identify and describe the measurement objectives and station requirements for the IHRF and the IGRF; as well as, mission requirements (gravity field, altimetry, GNSS, SAR, etc.);

3. Characterize the current stations (VLBI, SLR, GNSS, DORIS, IHRF, IGRF) in terms of performance for the ITRF and other applications; What are they contributing?

4. Using the performance of the current stations, stations with planned upgrades, and new stations in process, project the network status 5, 10 and 15 years in the future;

5. Using this information and the results from the newest releases of the ITRF, the IHRF and IGRF, project the quality of the ITRF and other data products 5, 10 and 15 years ahead; What do we think we can achieve?

6. Examine augmentation options of co-locations in space to these projected networks; to achieve the ITRF, IHRF and IGRF requirements; Simulations and engineering studies; what benefit could we get; some talks already given by the PLATO SC members; revisit studies already presented to ESA and NASA;

7. Can we get full Co-location value from SLR and VLBI sites located 100 – 200 km apart, but connected with redundant GNSS measurements from a continuously operating regional network;

8. What software and modeling needs require updates in order to improve the results; Survey of Analysis groups;

9. Explore options for sites in Latin America, Africa, and Oceania; the UN GGIM should be a useful to help attract new partners and partnerships

10. Help sell this program to interested parties in critical regions; nurture partnerships.

2.2.2 BN&O Standing Committees and Working Group

The main activities for the Bureau of Networks and Observations are shown in Fig. 2.2.1. The activities are divided into the categories of coordination, level of effort for the Services, level of effort for the Committees/Working Group, most of the activities over the next two years are level of effort. The deployment and upgrading of field stations has been seriously delayed due to administrative issues and the Panvirus-19 epidemic.

2.2.2.1 Standing Committee on Performance Simulations & Architectural Trade-Offs (PLATO)

Objectives

The PLATO Committee / Working Group has currently 12-member groups working on simulations and data analysis covering the full range of existing ground and space assets, including VLBI, SLR, GNSS, and DORIS. The main focus is on how do we use existing observation capabilities (stations, observation concepts, tracking performance, etc.) including co-location in space with existing and new dedicated satellites to best support GGOS planning and implementation.

Project future network capability and examine trade-off options for station deployment and closure, technology upgrades, the impact of site ties, additional space missions, etc. to maximize the utility of the GGOS assets:

- Use simulation techniques to assess the impact on reference frame products of network configuration, system performance, technique and technology mix, colocation conditions, site ties, space ties (added spacecraft, etc.), analysis and modeling techniques, etc.;
- Use and developing improved analysis methods for reference frame products by including all existing data and available co-locations (i.e., include all satellites and use all data types on all satellites);
- Make recommendations on network configuration and strategies based on the simulation and trade-off studies.

Investigations that are being included in the PLATO activity include studying the impact of:

- The full range of existing ground and space assets:
- GNSS assets (ground and space)
- SLR (beyond Lageos-1 and -2) including ranging to GNSS satellites;
- LLR assets
- VLBI assets including tracking of GNSS satellites;
- Co-located assets in space (e.g. GRACE, OSTM/Jason-2)
- Mixture of existing legacy stations and simulated next generation stations
- Improved GNSS antenna calibrations and clock estimation strategies (GNSS alone or when in combination with SLR, VLBI, and DORIS)
- Anticipated improved performance of current systems:
- Simulate the impact of upgrading existing stations and their procedures
- Simulate the impact of additional ground surveys at colocation sites (site ties)
- Potential future space assets: - Co-locate all four techniques in space on a dedicated satellite

Tasks

- Examining trade-off options for station deployment and closure, technology upgrades, the impact of site ties, etc. and project future network capability based on network configuration projected by the BNO or relevant IAG services (IGS, ILRS, IVS, IDS);

- Investigating the impact of improved SLR tracking scenarios including spherical satellites, LEOs, and GNSS satellites and VLBI satellite tracking on reference frame products;
- Identifying technique systematics by analyzing short baselines, data from new observation concepts, and available co-locations (e.g., consistent processing of LEO and ground-based observations);
- Investigating the best-practice methods for co-location in space and assessing the impact of co-location in space on reference frame products based on existing satellites and by simulation studies for proposed missions.

2.2.2.2 Standing Committees on Data and Information

Objectives

Near term Metadata activity (NASA CDDIS)

CDDIS continues to add new data and derived product collections and further populate collection-level metadata stored in the Earth Observation System Data and Information System (EOSDIS) Common Metadata Repository (CMR). CDDIS is an EOSDIS Distributed Active Archive Centers (DAACs) and thus utilizes the EOSDIS infrastructure to manage collection and granule level metadata describing CDDIS archive holdings; these metadata include 120 published DOIs representing DORIS, GNSS, and SLR data and derived product collections archived at the CDDIS archive. Since the AGU Fall Meeting 2019 the CDDIS actively participates in the GGOS DOI Working Group, sharing NASA Earth Science Data and Information System (ESDIS) DOI methods and best practices with the greater Geodesy community.

Activities underway at CDDIS:

1. Complete collection level metadata related to CDDIS data and derived product holdings in the EOSDIS Common Metadata Repository (CMR)
2. Continue to re-ingest CDDIS data and derived product holdings in order to extract granule level metadata linked to these new collection level records

Longer-Term Metadata activity /Geoscience Australia)

Geoscience Australia is working on the Development of a Geodesy Markup Language (GeodesyML), for the GNSS community; potential for expansion to the other space geodesy techniques and GGOS. The current study is identifying metadata standards and requirements, assessing critical gaps and the how these might be filled, what changes are needed in the current standards, and who are the key people who should work on it (more comprehensive scheme). The schema that would be used by its elements for standardized metadata communication, archiving, and retrieval. First applications would be the automated distribution of up-to-date station configuration and operational information, data archives and catalogues, and procedures and central bureau communication. One particular plan of great interest is a site metadata schema underway within the IGS Data Center Working Group. This work is being done in collaboration with the IGS, UNAVCO, SIO, CDDIS, and other GNSS data centers. The current activity is toward a means of exchange of IGS site log metadata utilizing machine-to-machine methods, such as XML and web services, but it is expected that this will be expanded to the other Services to help manage site related metadata and to other data related products and information. Schema for the metadata should follow international standards, like ISO 19xxx or DIF, but should be extendable for technique-specific information, which would then be accessible through the GGOS Portal.

Tasks:

Activities underway at CDDIS:

1. Complete collection level metadata related to CDDIS data and product holdings in the EOSDIS Common Metadata Repository (CMR)
2. Re-ingest CDDIS data holdings in order to extract granule level metadata linked to these new collection level records

Activities underway in Geodesy Markup Language (GeodesyML) System

1. Review and document the metadata and standards requirements of precise positioning users in expected high use sectors (e.g. precision agriculture, intelligent transport, marine, location-based services etc.).
2. Assess and document the critical gaps in standards which restrict how Findable Accessible Interoperable and Reusable (FAIR) precise positioning data is for the expected high use sectors.
3. Record use cases of standards being applied well and the benefits it provides to users.
4. Review the "use cases" of geodetic data developed by Geoscience Australia and the IGS Data Center Working Group. (https://drive.google.com/drive/folders/1L792ImLktAiAbmhX9WZhvHrXB3BMD00G?usp=sharing) and document what work and time would be required to ensure these use cases can be met in international standards. This could be:
   - Identify which gaps can be filled by GeodesyML
   - Identify which components of GeodesyML would be better, handled by / integrated with, existing standards (such as TimeSeriesML, SensorML, Observations and Measurements) where possible.
   - Identify which components of already existing international geospatial infrastructure can be approached (such as the European Inspire initiative)
   - Advise on who we should engage with from the OGC/ISO community to facilitate a change to a standard to meet our requirements.
5. Work with Project Partners to develop and test other use cases (e.g. integration of geodetic data with geophysics data (e.g. tilt meters), Intelligent Transport

Sector data, mobile applications). Then, document what work and time would be required to ensure these use cases can be met in international standards.

6. Provide advice on how to best engage with the right communities to learn from their experiences, test their tools and influence the development of required standards.

Table 1: Research Projects

Research Project	Project Component
RP 1 – Improving the value of Positioning Australia Products	RP 1.1: Develop and confirm GNSS value chains
	RP 1.2: Identification of gaps in current standards
	PR 1.3: Developing and distributing customized GNSS metadata profiles for industry
RP 2 – Extension of GeodesyML	PR 4.1: OGC Innovation Program
	PR 4.2: GeodesyML adopted as a community standard

Table 2: Tasks

Project Component	Task Details
RP 1.1	• Engage with representatives from all industry sectors to develop GNSS value chain diagrams (how users get and use precise positioning data).
RP 1.2	• To identify and address any remaining critical gaps in ISO and OGC standards which will inhibit uptake of precise positioning data.
RP 1.3	• Establish detailed, community-specific requirements for FAIR geodetic and positioning metadata and setup a FAIRness compliance test. • Develop a GNSS metadata profile(s) for specific user sectors. • Develop education material to explain how user groups can use GNSS metadata profiles. • Engage with industry to test the GNSS metadata profile(s) for user acceptance. • Revise GNSS metadata profile(s) based on user feedback. • Distribute via GA website.
RP 4.1	• Expand the information model of GeodesyML with required metadata for end-users (as identified in RP 1). • Revise and expand the information model of GeodesyML to ensure the provided precise positioning data is FAIR. • Investigate applicability of OGC API for provision of precise positioning data to the end-users.

	• Supervise improvement of GeodesyML and coordinate these efforts within OGC Innovation Program. • Development, implementation and testing of GeodesyML against current standard practice
RP 4.2	• Engage with Standards Australia to develop an adoption path for GeodesyML in ISO and OGC. • Engage with ISO and OGC to propose GeodesyML as a community standard. • Work through ISO and OGC process to respond to changes and suggestions made by ISO and OGC

Table 3: Deliverables

Project Component	Deliverable Details	Due
RP 1.1	GNSS value chain diagrams for 17 different user applications; 2 for each of the high value sectors and 1 for each of the other identified sectors.	31 Dec 2020
RP 1.2	A strategy to address each of the gaps in the standards identified in RP 1.1 and PA1003.	30 Jun 2021
RP 1.3	GNSS metadata profile(s) addressing specific Positioning Australia user sectors.	31 Dec 2021
RP 4.1	Acceptance of GeodesyML in the OGC Innovation Program and adherence to terms of the Program.	30 Jun 2021
RP 4.2	Incorporate improvements to GeodesyML as identified in RP 1 and RP2.	31 Dec 2022

2.2.2.3 Standing Committee on Satellite Missions

Objectives

Improve coordination and information exchange with the missions for better ground-based network response to mission requirements and space-segment adequacy for the realization of GGOS goals

- Advocate, coordinate, and exchange information with satellite missions as part of the GGOS space infrastructure, for a better ground-based network response to mission requirements and space-segment adequacy for the realization of the GGOS goals.
- Assess current and near-future satellite infrastructure and their compliance with GGOS 2020 goals;
- Support proposals for new mission concepts and advocate for needed missions;
- Interfacing and outreach with other components of the Bureau; especially the ground networks component, the simulation activity (PLATO), as well as the Bureau of Standards and Products.

Tasks

- Set-up of a new concept of the Standing Committee to increase participation by potential members;
- Continue the regular activities, i.e. updating the two central lists, supporting future satellite missions, etc.
- Work with the Coordinating Office to set up and maintain a Satellite Missions Committee section on the GGOS website;
- Evaluate the contribution of current and near-term satellite missions to the GGOS 2020 goals;
- Work with GGOS Executive Committee, Focus Areas, and data product development activities (e.g., ITRF) to advocate for new missions to support GGOS goals;
- Support the Executive Committee and the Science Committee in the GGOS Interface with space agencies;
- Advocate and support national and international space agencies in their processes towards future gravity field missions, by providing material and taking part in studies that support the realization of such concepts;
- Increase the exchange and collaboration with PLATO; set up a more formal procedure of collaboration; discuss needs and run simulations to study the impact of future satellite missions, identify gaps for fulfilling the GGOS goals, etc.
- Evaluation of cubesats and cubesat formations as complementary element of the GGOS (satellite) infrastructure

2.2.2.4 IAG Joint Working Group on Site Survey and Co-location (w/ IERS) 1.2.1:

The Working Group has a new set of terms and has received confirmation of new participants in the group. We would continue to encourage participation from any agency or community that is conducting research, improving protocols, or completing field surveys of local ties as sites with various space geodesy techniques present. Our group has representation from all of the techniques and has continued to share improved protocols, technologies, and instrumentation to provide the most accurate tie measurements possible for all sites around the world. We reminded participants to share their contributions of local tie data for inclusion into ITRF2020.

- Roles/Objectives
  - Enhance and improve knowledge of local tie surveys through applied field practice, research, and dissemination of materials developed.
  - Share methodology of existing surveys to maintain consistency and improve future results by isolating systematic errors.
  - Share results and research internationally to improve protocols and coordinate work.
  - Coordinate the collection of local tie survey data results and associated metadata in a consistent fashion.
- Committee leads and Membership (could be a link)
  - R. Hippenstiel, S. Bergstrand

    - https://www.iers.org/IERS/EN/Organization/WorkingGroups/SiteSurvey/sitesurvey.html (To be updated.)
- Recent progress/Plans
    - Improvements made to standardizing report and data submissions of local tie surveys to provide consistency across all agencies. Survey data has recently been reported with new standards in place.
    - Additional standard operating procedures are being written (NGS/USA) to account for new routines and laser tracking instrumentation being used in recent local tie surveys.
    - Local tie surveys were largely put on hold due to COVID-19 pandemic.
    - Upcoming surveys planned at National Radio Astronomy Observatory (New Mexico, USA) and Goddard Geophysical and Astronomical Observatory (Maryland, USA).
    - Group is continuing to explore methodologies to measure and quantify antenna deformation. Research and continued field tests using laser scanning and terrestrial inSAR have been discussed.
    - US (NGS) team has developed deflection of vertical (DoV) measurement capabilities utilizing a robotic total station and camera.
    - Submission of local tie metadata for the inclusion of the ITRF2020 development.
    - NGS and NGA will complete side-by-side local tie survey observations and training in May.
- Key issues
    - Investigate thermal and gravitational deformation
    - Consider importance and inclusion of DoV observations
    - Consistent formatting and reporting of survey results
- Key Publications and Meetings
    - Most conferences were cancelled though we've maintained communications about chairing sessions at upcoming events.
- Longer-term Goals
    - Implement newly developed DoV collection procedures after testing and documentation is complete.
    - Further the discussions and potential field protocols for deformation.
    - Discuss and study creating ties between sites of further distances by incorporating continuous GNSS at more facilities.

2.3 Resources

The resources that make the Bureau possible are tabulated in Table 1.3-1. The participating institutions cover material resources, travel, and other costs such as meeting rooms and teleconferences. The Bureau plan recognizes that we can declare the ideal, we can issue guidelines and standards, and we can advocate, but we have very limited control over the allocation of resources except through persuasion. The realization of the infrastructure will depend upon the resources that our participants are willing to contribute, the cooperation that participants are willing to undertake, geographic, political and other practical realities, and the influence that we as GGOS can exert.

3.0 CHANGE LOG

Table 3-1: Bureau of Networks and Observations Implementation Plan Change Log

VERSION	RELEASE DATE	SYNOPSIS OF RELEASE
0.1	141207	First draft for review
0.2	150326	Draft submitted to CB for review
0.3	150531	Second draft submitted to CB for review
0.4		
0.5	160106	Plan 2017 -18; Draft 2
0.6	170201	Plan 2017 – 18; Draft 3
0.7		Plan 2020 - 21; Draft
0.8	210304	Plan 2020 – 22; Draft for review
0.9	210322	Plan 2022 – 22; Final & approved version

4.0 Appendices

4.2 Abbreviations

AGU	American Geophysical Union
AOGS	Asia Oceania Geosciences Society
ASI	Agenzia Spaziale Italiano, Italy
BKG	Bundesamt für Kartographie und Geodäsie, Frankfurt/Main, Germany
BN&C	Bureau of Networks and Communication
BN&O	Bureau of Networks and Observations
BP&S	Bureau of Products and Standards
CB	Coordinating Board
CEOS	Committee on Earth Observation Systems
CfA	Center for Astrophysics, USA
CHAMP	Challenging Mini-Satellite Payload

CO	Coordinating Office
CSM	Committee on Satellite Missions
CRF	Celestial Reference Frame
DORIS	Doppler Orbitography by Radiopositioning Integrated on Satellite
EC	Executive Committee
EGU	European Geosciences Union
ESA	European Space Agency
FTE	Full-Time Equivalent
GEO	Group on Earth Observation
GEOSS	Global Earth Observation Systems of Systems
GFZ	GeoForschungsZentrum, Germany
GGIM	Global Geospatial Information Management
GGOS	Global Geodetic Observing System
GIMS	GGOS Integrated Master Schedule
GGOS	Global Geodetic Observing System
GLOSS	Global Sea Level Observing System
GML	Geography Markup Language
GNSS	Global Navigation Satellite System
GOCE	Gravity field and steady-state Ocean Circulation Explorer
GOOS	Global Ocean Observing System
GPS	Global Positioning System
GRACE	Gravity Recovery And Climate Experiment
GRACE-FO	Gravity Recovery And Climate Experiment Follow-On
GRASP	Geodetic Reference Antenna in Space
GSFC	Goddard Space Flight Center, USA
GTRF	Global Terrestrial Reference Frame
IAG	International Association of Geodesy
IAU	International Astronomical Union
ICSU	International Council for Science
IDS	International DORIS Service
IERS	International Earth Rotation and Reference Frame Service

IfE	Institut fuer Erdmessung, University of Hannover, Germany
IGFS	International Gravity Field Service
IGN	Institut National de l'Information Géographique et Forestière, France
IGS	International GNSS Service
IGRF	International Gravity Reference Frame
IHRF	International Height Reference Frame
ILRS	International Laser Ranging Service
IOC	Intergovernmental Oceanographic Commission
ITRF	International Terrestrial Reference Frame
IUGG	International Union of Geodesy and Geophysics
IVS	International VLBI Service
JPL	Jet Propulsion Laboratory, USA
LAGEOS	LASer GEOdynamics Satellite
LARES	LAser RElativity Satellite
LARGE	LAser Ranging to GNSS s/c Experiment
LEO	Low Earth Orbiter
NASA	National Aeronautics and Space Administration, USA
NOC	National Oceanography Centre, UK
PLATO	Performance Simulations & Architectural Trade-Offs
PM	Polytechnic University of Milan, Italy
PP	PowerPoint
PSMSL	Permanent Service for Mean Sea Level
s/c	Spacecraft
SLR	Satellite Laser Ranging
SMWG	Satellite Missions Working Group
SOPAC	Scripps Orbit and Permanent Array Center, USA
SP	SP Technical Research Institute of Sweden
ST&C	Survey Ties and Co-location
TBD	To Be Determined
TIGA	IGS Tide Gauge Working Group
ToR	Terms of Reference

TRF	Terrestrial Reference Frame
TUM	Technical University of Munich, Germany
UMBC	University of Maryland, Baltimore County, USA
UN	United Nations
VLBI	Very Long Baseline Interferometry
WG	Working Group

4.3 Glossary

[LIST ANY DEFINITIONS RELEVANT TO THE PLAN USING TABLE 4.3-1]

[CONSIDER CREATING A GGOS-COMMON LIST OF DEFINITIONS ON-LINE AT THE GGOS PORTAL/WEBSITE]

Table 4.3-1: Terms and Definitions

TERM	DEFINITION
[Term goes here]	[Definition goes here]
[Term goes here]	[Definition goes here]

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