

**Seventh Session of the UN Committee of Experts on Global Geospatial Information
Management
31 July - 4 August 2017, New York**

Report: UN-GGIM Geospatial Societies (formerly the Joint Board of Geospatial Information Societies).

<http://www.fig.net/jbgis/>

1. Summary

This document provides a report from the UN-GGIM Geospatial Societies Thematic Group (formerly the Joint Board of Geospatial Information Societies - JBGIS) to the Seventh Session of the UN Committee of Experts on Global Geospatial Information Management 31 July – 4 August 2017, New York.

2. UN-GGIM Geospatial Societies (UN-GGIM GS)

The UN GGIM Geospatial Societies Thematic Group is a coalition of the Presidents, Secretaries-General or equivalent office bearers or their nominees that lead recognized international organisations involved in the coordination, development, management, standardisation or regulation of geospatial information and related matters. These organisations are:

- Global Spatial Data Infrastructure (GSDI) Association
- IEEE Geoscience and Remote Sensing Society (GRSS)
- International Association of Geodesy (IAG)
- International Cartographic Association (ICA)
- International Federation of Surveyors (FIG)
- International Geographical Union (IGU)
- International Map Industry Association (IMIA)
- International Society of Photogrammetry and Remote Sensing (ISPRS)

UN GGIM GS meets formally once each year, typically when the UN-GGIM Committee of Experts meet, and informally when schedules permit.

3. Report content

This report provides an update on the activities of the organisations listed above where these have been provided.

4. Global Spatial Data Infrastructure (GSDI) Association

4.1 Summary

GSDI continues work on two Projects, i) focusing on Marine SDE Best Practice, led by members KU Leuven and member, LETG-BREST GEOMER, and ii) the NSDI Global Index Project. Both projects will complete in 2018;

Four GSDI Small Grants Program projects concluded in 2016, gratefully supported with funding from GSDI member Natural Resources Canada. The call for proposals for 2017 closed on 8 June 2017 resulting in 31 proposals, which are under review for funding;

GSDI continues to deliver a programme of capacity building webinars and workshops;

The GSDI 15 World Conference held in Taipei, Taiwan, with the theme “Spatial Enablement in the Smart Homeland” was hosted by GSDI member Taiwan Association for Disaster Prevention Industry (TADPI). The conference was very well attended and produced a digital Proceedings and a conference book, both accessible from the GSDI website <http://gsdiassociation.org/>.

4.2 Introduction, Background

The Global Spatial Data Infrastructure Association (GSDI) exists to promote international cooperation and collaboration in support of local, national and international SDI developments that will assist members to better address social, economic, and environmental issues of pressing importance in their nations.

GSDI has 27 Organizational Members from national and regional associations, government agencies, academia and private industry, from 17 countries, including 4 regional (transnational) organizations, and 45 Individual Members. GSDI has MoUs with the International Cartographic Association (ICA), the International Federation of Surveyors (FIG) and the International Society for Photogrammetry and Remote Sensing (ISPRS), the International Society for Digital Earth (ISDE), and the Centre for Disaster Management and Public Safety (CDMPS) at the Univ. of Melbourne for joint promotion of activities.

4.3 Activities, Areas of Work

- a. GSDI has Special Consultative status with UN ECOSOC since 1 May 2014. GSDI promotes the open data principles of GEO/GEOSS, and is involved in SDI capacity building activities in many developing nations via the GSDI Small Grants Program. The Association works with the International Hydrographic Organization (IHO) Marine SDI Working Group and is represented at both global and regional UN Global Geospatial Information Management (GGIM) meetings since 2014. GSDI are also represented on the Open Geospatial Consortium (OGC) Marine Domain Working Group.
- b. As to representation at international meetings, since the last report in June 2016:
 - Dr Rajabifard represented GSDI at the UN GGIM Expanded Bureau meeting at UN HQ in New York on 7-9 December 2016;
 - President David Coleman represented GSDI at UN GGIM 6 in New York in August 2016;
 - GSDI Delegate for Member PAIGH represented the Association at the UN GGIM Americas meeting held in Mexico City, Mexico, on 5-6 October 2016;
 - GSDI member Dr Gabor Remetey-Fülöpp represented GSDI at the UN GGIM Regional Committee for Europe meeting in Budapest in November 2016, at which meeting GSDI was officially welcomed as an Observer to the Committee;
 - Dr Remetey-Fülöpp, past-President Dr Rajabifard and other members represented GSDI at Locate 7/Digital Earth 10 in Sydney in April 2017;
 - Dr Remetey-Fülöpp represented GSDI at the CEOS WGISS-43 meeting in April 2017;
 - GSDI President Dave Lovell and Project Leader Georgina Chandler presented the GSDI Project “Towards a Global Assessment of National Spatial Data Infrastructures” at the 7th session of UN GGIM Europe in June in Brussels, Belgium.
- c. Work continues on two GSDI Projects, focusing on Marine SDE Best Practice, led by members KU Leuven and member, LETG-BREST GEOMER, which started in November 2015, and the NSDI Global Index Project. Both these projects will complete their work in 2018 and have conducted multiple workshops and webinars in the past year, including at the GSDI 15 World Conference.
- d. Four GSDI Small Grants Program projects concluded in quarter 3 of 2016, gratefully supported with funding from GSDI member Natural Resources Canada. The call for proposals for 2017 closed on 8 June 2017 resulting in 31 proposals, which are under review for possible funding as of the date of this report.
- e. The GSDI 15 World Conference was held in Taipei, Taiwan, from 29 November to 2 December 2016 under the theme “Spatial Enablement in the Smart Homeland” hosted by GSDI member Taiwan Association for Disaster Prevention Industry (TADPI). The conference was very well attended and produced a digital Proceedings and a conference book of selected and extended peer-reviewed papers, both accessible from the GSDI website.

4.4 Priority Issues and Challenges

The main activities of GSDI are: 1) supporting growth of harmonised local, national, and regional SDIs that are globally interoperable; 2) fostering international communication and collaborative efforts for advancing SDI innovations; 3) supporting interdisciplinary research and education that advances SDI concepts and methods; and 4) promoting access to, and appropriate use of, public geographic information. Main outreach and networking activities include the GSDI World Conferences, seminars and workshops, the monthly global and regional newsletters and discussion forums, individual capacity building actions, and support to SDI initiatives in developing nations via the GSDI Small Grants Program and targeted training activities. All conference papers and proceedings are available on an open access basis from the GSDI website.

4.5 Perspectives/Outlook, Future Plans

Through its capacity building activities, GSDI provides support to national and global geospatial initiatives for all those working in SDI implementation, offering global networking and learning opportunities between students, young professionals and SDI experts in tackling geospatial interoperability issues that are at the core of SDI implementation globally. More details on GSDI activities can be found on their web site <http://gsdiassociation.org>.

5. IEEE Geoscience and Remote Sensing Society (GRSS)

No report submitted.

6. International Association of Geodesy (IAG)

The International Association of Geodesy has established an official position paper w.r.t. the UN-GGIM Global Geodetic Reference Frame, included as Annex A to this report.

7. International Cartographic Association (ICA)

7.1 Summary

The International Cartographic Association (ICA) is the world authoritative body for cartography and GI Science. The mission of the ICA is to promote the disciplines and professions of cartography and GIScience in an international context.

7.2 Introduction, Background

The mission of the ICA is to promote the disciplines and professions of cartography and GIScience in an international context.

7.3 Activities, Areas of Work

- a. 2016 was the International Map Year (IMY). In 2014 ICA was endorsed by UN-GGIM to organise the International Map Year. It was a worldwide celebration of maps and their unique role in our world. Among the objectives of the IMY:
 - making maps visible to decision makers, citizens and school children in a global context,
 - demonstrating how maps and atlases can be used in society,
 - showing how information technology can be used in getting geographic information and producing one's own maps,
 - displaying different types of maps and map production,
 - showing the technical development of mapping and atlas production,
 - showing the necessity of a sustainable development of geographic information infrastructures, and
 - increasing the recruitment of students to cartography and cartography-related disciplines.
- b. The book "The World of Maps" (<http://mapyear.org/the-world-of-maps-book/>) is probably the most visible product of IMY. It is available in multiple languages and freely downloadable.
- c. During the UN-GGIM 2016 meeting in New York, a map poster exhibition was organized. It offered a special cartographic perspective on the sustainability goals. The (revised) posters are available for download at <http://icaci.org/maps-and-sustainable-development-goals>.
- d. In our International Journal of Cartography an article describing the historical, current and future developments of cartography and ICA has been recently published "Of maps, cartography and the geography of the International Cartographic Association" authored by M.J. Kraak and S.I. Fabrikant.
- e. <http://dx.doi.org/10.1080/23729333.2017.1288535>.

7.4 Priority Issues and Challenges

- a. Further priority issues of ICA include the further development of the Research Agenda of Cartography and GI Science, especially in the context of the recently endorsed full membership of ICA in the International Council of Science (ICSU). ICA aims to contribute significantly through this partnership to scientific efforts in tackling global challenges in relation to geospatial information management.
- b. A special focus is given as well to outreach programmes and capacity building. In several related workshops and activities in the last few years it became more than visible that several countries and regions of the world have a high demand and necessity in capacity building towards modern cartography tools, techniques and methods. In this framework, a scholarship programme has been launched to allow easier participation in ICA Commissions activities and our Global and Regional Conferences.
- c. ICA is actively involved in the "Geo4All" initiative (<http://www.geoforall.org/>), allowing geospatial education, materials and instruments accessible for all. This, accompanied with a long record of highly successful ICA hands-on workshops on modern cartography, can be requested from ICA by UN-GGIM national delegations.

7.5 Perspectives/Outlook, Future Plans

Finally, it has proven to be a most successful strategy in the context of Global Geospatial Information Management to allow for a better awareness of the crucial role of the map as the interface between geo-data and human users. In this context, ICA will continue to offer its expertise and consultancy for understanding the context of why maps are important, relevant and attractive, thus are key in making all geo-domains being able to reach out beyond the limits of the disciplines to all citizens. More details on ICA activities can be found on their web site <http://icaci.org>.

8. International Federation of Surveyors (FIG)

8.1 Summary

As a United Nations and the World Bank Group recognized non-governmental organization, The International Federation of Surveyors (FIG) is seeking to collaborate and to ensure that the disciplines of surveying and all who practice them are relevant and meeting the needs of both the community and the market we are present. This worldwide professional community measures, maps, estimates, costs, values, assesses, models, plans and manages the natural and built environment for the effective planning and efficient administration of the land, the seas and any structures thereon. The FIG vision is of a modern and sustainable surveying profession in support of society, environment and economy by providing innovative, reliable and best practice solutions to our rapidly changing and complex world. For the 2015-2018 time period FIG council has agreed on the following overall theme: *"Ensuring the Rapid Response to Change, Ensuring the Surveyor of Tomorrow"*

8.2 Introduction, Background

The FIG seeks to collaborate and to ensure that the disciplines of surveying and all who practice them are relevant and meeting the needs of both the community and the market we service. This worldwide professional community measures, maps, estimates, costs, values, assesses, models, plans and manages the natural and built environment for the effective planning and efficient administration of the land, the seas and any structures thereon. The FIG vision is of a modern and sustainable surveying profession in support of society, environment and economy by providing innovative, reliable and best practice solutions to our rapidly changing and complex world, acting with integrity and confidence about the usefulness of surveying, and translating these words into action.

8.3 Activities, Areas of Work

- a. The FIG Working Week 2017 was held in Helsinki, Finland 29 May -2 June 2017 with the overall theme “Surveying the world of tomorrow – From digitalization to augmented reality”. More than 1400 participants from 90 countries attended the Working Week. The plenary sessions included various aspects of digitalization under the headlines: Living of Tomorrow – In a Digitalised World, Professional behaviour – In a Digitalised World and The Contribution of our Profession – In a Digitalised World. The Working Week offered around 400 presentations during the three conference days and institutional partners were UN-Habitat/GLTN, FAO, UN-GGIM and the World Bank. There were several side events in connection with the Working Week, a workshop on BIM, Young Surveyors Conference, and a History Symposium.
- b. In September, a High-Level FIG/World Bank Conference on Sustainable Real Estate Markets Policy Framework and Necessary took place, raising awareness of the necessary strategic and policy framework in order to formalize and create sustainable real estate markets as a pillar on which to build robust economic urban growth, eliminate urban poverty and meet the vision of the global sustainable development agenda of 2030. The Workshop was organised by the Task Force on Property Markets in cooperation with FIG Commission 9. Commission 7 had their yearly event in Coimbra, Portugal, organised together with the Portuguese Engineers Professional Association. Commission 3 held their event in Iasi, Romania – From Volume to Quality: Bridging the Gap for Spatial Data Infrastructure, investigating the processes and conventions dealing with geospatial data and big geodata. Commission 5 convened a half-day presentation and discussion forum on reference frames as part of the United Nations/Nepal Workshop on the Applications of Global Navigation Satellite Systems held from 12–16 December 2016 in Kathmandu. The 5th International FIG Workshop on 3D Cadastre took place in Athens, Greece, and a Land consolidation and land readjustment for sustainable development Workshop was held in Apeldoorn, the Netherlands in cooperation with FAO, Landnet, FIG and Kadaster, Netherlands – with support from UN Habitat, the Global Land Tool Network and the World Bank. Focus was on urban and rural environment and to applications for sustainable development. The symposium concluded with the ‘Apeldoorn declaration on land consolidation and land readjustment for sustainable development’. The Africa Regional Network (ARN) Capacity Development Workshop was held in Abidjan, Ivory Coast, with the theme, “Ensuring Good Land Governance Practices in the Land Profession and what you can do about it” appealed to those wishing to understand the international land governance initiatives, specifically the Voluntary Guidelines on Good Governance (VGGT’s). Another FIG Regional meeting was held in the newly established Asia/ Pacific Network. FIG Young Surveyors held several meetings in various regions around the world.
- c. Cadastral Template 2.0 - The Cadastral Template is a unique worldwide Comparison of Cadastral Systems consisting of Cadastral country reports based on a jointly developed PCGIAP/FIG template. The Cadastral Template was established under UN mandate by Resolution 4 of the 16th UNRCCAP in Okinawa, Japan in July 2003 including UN endorsement for cooperation with UN-ECE WPLA, UN-ECA CODI, and PCIDEA. Cadastral Template version 2.0 was published in 2016. PCGIAP Working Group 3 “Cadastre” cooperates with FIG Commission 7 to place the country information jointly on www.cadastraltemplate.org.
- d. Cooperation with the United Nations - One of the larger events in 2016 was the United Nations Conference on Housing and Sustainable Urban Development – Habitat III meeting. The conference is a significant milestone emerging from over two years of preparatory meetings. Habitat III is aimed at steering the course of global urbanization towards environmentally sustainable and socially equitable development pathways. The New Urban Agenda aims at implementing the targets of Goal 11 in the Sustainable Development Goals, which specifically deals with making human cities and towns inclusive, safe, 14 resilient and sustainable. Key issues that were debated include climate change, as cities are responsible for 70% of the world’s greenhouse gas emissions, housing, migration, poverty, and inclusion.
- e. The 6th UN-GGIM meeting was held in August 2016 in New York with the attendance of FIG President Potsiou. Dr Christiaan Lemmen is FIG representative in UN-GGIM Expert Group on Land Administration and Management.
- f. The Food and Agriculture Organization of the United Nations (FAO) has worked with FIG for many years, focusing on how land professionals can help to improve governance of tenure, recognising that land provides the basis for everyone’s food and shelter, economic production and social, cultural and religious practices. During the FIG Working Week 2017 two sessions were dedicated to FAO and the Voluntary Guidelines, VGGT as part of the Action Statement agreed in 2016 between FIG and FAO. One session on Land Consolidation and FIG Academic Forum had the implementation of the VGGT as a theme.
- g. The Eleventh Meeting of the International Committee on Global Navigation Satellite Systems (ICG) was held in Sochi, Russia. The ICG has been formed as a result of recommendations of the UN Committee on the Peaceful

Use of Outer Space (COPUOS), as ratified by the General Assembly of the UN. FIG is an Associate Member of ICG. FIG Vice President Mikael Lilje attended as FIG representative to UNOOSA.

h. New FIG Publications

- FIG Publication 68 – The FIG Christchurch Declaration, FIG Report 2016.
- FIG Publication 52 – translated into French and Japanese. The publication is now available in four languages (also English and Arabic).

8.4 Issues and Challenges

- a. For just over two years now FIG/Commission 5 has been involved in the United Nation's Global Geodetic Reference Frame. FIG has been a team member of the Global Geodetic Reference Frame (GGRF) Working Group which wrote the UN Resolution. The GGRF Working Group is responsible for developing a Roadmap which describes how the UN will implement the geospatial components of the UN Resolution. During the summer of 2016, the team rushed to complete the GGRF Roadmap before the General Assembly. The final version was presented to the UN General Assembly in early August and describes how governments and geodetic/geospatial agencies can contribute to establishing and maintaining a Global Geodetic Reference Frame. Having a geodetic infrastructure is critical for many geographic information systems, maps and nautical charts as well as for all positioning and navigation systems/applications. The National Geodetic Survey plays a critical role in establishing the National Spatial Reference System and considered one of the World's leaders in advancing the fields of geodesy and geoinformatics.
- b. The Global Land Tool Network (GLTN) is an alliance of global, regional and national partners contributing to poverty alleviation through land reform, improved land management and security of tenure particularly through the development and dissemination of pro-poor and gender-sensitive land tools and approaches within the continuum of land rights framework. For the term 2016–17 FIG President Chryssy Potsiou is in the lead of the professional cluster and is member of the International Advisory Board that provides a strategic direction to the network operations. The professional cluster has 13 members. At FIG Working Week 2017 GLTN had five special sessions. In September 2016 FIG and GLTN held an Expert Group Meeting in Greece on Valuation of Unregistered Lands and Properties. There is consensus that about seventy percent of land ownership units in developing countries are not formally registered and the initiatives for land registration are not achieving the desired results. In some developed countries, also a certain part of the land is not registered. GLTN is thus working to develop a tool for valuation of unregistered land and properties that can benefit the vulnerable groups and support operationalization of the continuum of land rights concept.
- c. The 17 UN Sustainable Development Goals and FIG - The Sustainable Development Goals cover a diverse range of issues including gender equity, sustainable cities, access to clean water, land issues, and good governance. Surveyors play an essential role in several of the 17 SDGs. FIG aims to make an active effort on those goals that involve surveyors and surveying in order to assist in achieving the goals and their targets by 2030 and set the world on a path towards sustainable development.

8.5 Perspectives/Outlook, Future Plans

At the FIG Congress 2014 the new leadership was elected, and the new President, Chryssy Potsiou, together with her Council took over the leadership of FIG on 1 January 2015. The General Assembly voted on the destination for the FIG Working Week 2021 that will take place in Accra, Ghana. Three new member associations were approved. More details on FIG activities can be found on their web site <http://www.fig.net>.

9. International Geographical Union (IGU)

No report submitted.

10. International Hydrographic Organization (IHO)

Withdrew from JBGIS in June 2016. Has independent representation at UN GGIM.

11. International Map Industry Association (IMIA)

11.1 Summary

The International Map Industry Association (IMIA) is a truly global organization that represents the business of maps. IMIA is where mapmakers, publishers, geospatial technology companies, distributors, location-based services and content producers come together to conduct the business of maps.

11.2 Introduction, Background

IMIA has a number of activities planned in our regions and continues to publish relevant content via our blog, member newsletter and social media.

11.3 Activities, Areas of Work

- a. IMIA Americas held its annual Strategic Planning Session in Las Vegas, NV USA on 12 January 2017. This was an opportunity for IMIA members to gather together and initiate the planning process for the year and beyond. This annual event is vital to the success of the association.
- b. IMIA Americas hosted its second annual Denver MeetUp event on 1 June 2016 at the University of Colorado. The MeetUp attendance increased over 20% this year and continues to provide a forum for leaders in the mapping industry to meet, network and be an active part of topical discussions and presentations.
- c. IMIA plans to expand its program of regional MeetUp events, with plans being made for a Meetup in Washington, DC tentatively scheduled for December 7 - 8 2017 as well as a member event at the Esri User Conference in July. Other venues under consideration for events are Seattle, Ottawa. And Mountain View, CA.
- d. The IMIA EAME Region is planning to continue its presence at the Frankfurt Bookfair with a collective stand for member companies and a networking event.
- e. IMIA has pledge continued support for the ICA/IMIA map award to be presented at the Esri User Conference in July.

11.4 Priority Issues and Challenges

The IMIA Boards are considering changes to the regional organization to better serve our member constituents.

11.5 Perspectives/Outlook, Future Plans

More details on IMIA activities can be found on their web site <http://imiamaps.org>

12. International Society of Photogrammetry and Remote Sensing (ISPRS)

12.1 Summary

The International Society for Photogrammetry and Remote Sensing (ISPRS) is a non-governmental organisation devoted to the development of international cooperation for the advancement of the photogrammetry, remote sensing and spatial information sciences and their applications. The ISPRS promotes the extraction and utilization of information from imagery by encouraging and facilitating research and development in its areas of scientific activity, advancing knowledge through scientific networking, stimulating international cooperation, pursuing interdisciplinary integration, facilitating education and training, enhancing and exploring new applications, and developing public recognition of photogrammetry, remote sensing and spatial information science. Photogrammetry is the science and technology of extracting reliable three-dimensional geometric and thematic information, often over time, of objects and scenes from image and range data. Remote sensing is the science and technology of capturing, processing and analysing imagery, in conjunction with other physical data of the Earth and the planets, from sensors in space, in the air and on the ground. Spatial Information Science is concerned with the modelling, storage, processing, retrieval, application and communication of information with a spatial reference.

12.2 Introduction, Background

- a. ISPRS entered a new quadrennial period on 20 July 2016 – the first day after the Closing Ceremony of the XXIII ISPRS Congress in Prague. The Society now has a new Council. The next Congress will be held in Nice in 2020. ISPRS has a new structure, with the previous eight Technical Commissions being replaced by five Technical Commissions, each with a President and Vice- President. The number of Working Groups is the same as in the previous 4-year period.
- b. After a lengthy discussion period, ISPRS has introduced a new structure with 5 commissions:

Commission I	Sensor Systems
Commission II	Photogrammetry
Commission III	Remote Sensing
Commission IV	Spatial Information Science
Commission V	Education and Outreach

12.3 Activities, Areas of Work

- a. The Society continues with its rich publication activity. Congress and the following workshops published many proceedings of both types – Archives (The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences) and Annals, (ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences).
- b. The activities of members are documented in a long list of scientific papers publicized in the ISPRS Journal of Photogrammetry and Remote Sensing and ISPRS International Journal of Geo-Information. ISPRS reaches out to its members via the ISPRS eBulletin. It brings news from recent events, on important activities of ISPRS, lists open access papers, etc.
- c. A significant phenomenon is also a long list of workshops (47 approved by ISPRS up to now) planned for this year, along with the third Geospatial Week which will be held in Wuhan on 18 – 22 September 2017 (<http://gsw2017.3snews.net>). Next year is the year of ISPRS Symposia. The five symposia will be held in China, Italy, Germany, The Netherlands and India.

12.4 Priority Issues and Challenges

Individual membership is popular - the numbers are constantly rising - which enlarges awareness of the Society, not only among members of Ordinary Members (91 countries from all over the world), but also in countries where no ISPRS Ordinary Member exists.

12.5 Perspectives/Outlook, Future Plans

More details on recent ISPRS activities can be found on the ISPRS web site <http://www.isprs.org>.

13. International Steering Committee for Global Mapping (ISCGM)

The resolution of the termination of ISCGM and the transfer of Global Map data to the Geospatial Information Section in the UN was adopted at the 23rd ISCGM meeting on 2 August 2016.

Annex A

Description of the Global Geodetic Reference Frame

Position paper adopted by the **IAG Executive Committee, April 2016**

Preamble

The United Nations General Assembly adopted the resolution on a Global Geodetic Reference Frame for Sustainable Development (A/RES/69/266) on February 26, 2015. The purpose of this document is a description of the Global Geodetic Reference Frame (GGRF), along with a brief description of its key components, as a realization of the Global Geodetic Reference System (GGRS).

This document forms the basis for a common understanding of the GGRF. It has been prepared by the International Association of Geodesy (IAG), the organization responsible for the science of geodesy. It thus outlines the IAG's perspective of what the GGRF is, and how it is realized through the contributions of the IAG components.

The mission of the IAG is the advancement of geodesy – the Earth science concerned with the size, shape, gravity field, and orientation of the Earth, including their temporal variations. The IAG supports the design of new satellite missions for gravity field determination, ocean and ice altimetry, and Earth observation in general, as well as promoting the importance of modern geodesy for addressing the needs of science and society for a variety of spatio-temporal and gravimetric reference frames. The Global Geodetic Observing System (GGOS) was established by the IAG to be the component that integrates the various geodetic contributions to ensure the quantification of our planet's changes in space and time with the highest accuracy and reliability. This is undertaken primarily through activities such as the maintenance, and continuous improvement of the geodetic instrumentation networks and space geodetic missions, and the combined analysis of geometric and gravimetric observations made by these networks using a variety of space and terrestrial geodetic techniques. In such a framework, the GGRF plays a key role in facilitating the integration of the different geometric and gravimetric observations, with the goal of providing reliable, high quality geodetic products and services.

The GGRF is intended to support the increasing demand for positioning, navigation, timing, mapping, and geoscience applications. The GGRF is essential for a reliable determination of changes in the Earth system, for natural disaster management, for monitoring sea-level rise and climate change, and to provide accurate information for decision-makers. Furthermore, due to globalization and interoperability requirements, there is a growing demand for spatial data infrastructure. Precise spatial information is needed in many areas of benefit to society, including transportation, construction, infrastructure, process control, surveying and mapping, and Earth sciences, and is especially important for monitoring progress towards the UN's Sustainable Development Goals.

General Concept

The GGRF includes the geometry and gravity field of the Earth and the Earth's orientation with respect to the celestial reference frame. It is based on geodetic observing systems, data centers, analysis centers, as well as combination and product centers. While the concept of a GGRF predominantly focuses on infrastructural, operational and technical issues, associated research and innovation activities are also to be considered.

The bases for the realization of the GGRF are the multiple geodetic observation infrastructures. GGOS defines the observation architecture at several levels: terrestrial networks with geometric and gravimetric observation stations, artificial satellites, the moon and the planets, and extragalactic objects (see Fig. 1). The permanent availability of state-of-the-art geodetic infrastructure, and scientific and technical personnel to generate the resultant products and services, is crucial for a sustainable GGRF.

Global Geodetic Reference System¹

Geodetic reference systems are the mathematical and physical models necessary to describe physical positions and gravity in a space-time environment. Fundamental geodetic theories and methodologies provide the framework for the definition of geodetic reference systems.

The GGRS comprises terrestrial and celestial components. The terrestrial component is a common reference for the geometry and the gravity field of the Earth², where a physical point P has a corresponding coordinate X , potential of the Earth gravity³ field W , physical height H , and gravity vector g . The following specifications apply:

- For the physical point P the potential $W_P = W(X)$ is evaluated at the coordinate X in the International Terrestrial Reference System (ITRS).
- The unit of time is the SI second. The unit of length is the SI meter.
- The physical height is the difference $-\Delta W_P$ between the potential W_P of the Earth gravity field at the considered point P and the geoidal potential of the level ellipsoid W_0 .
- The gravity vector g is the gradient of the potential of the Earth gravity field.
- Geometry and gravity are implicit functions of time.
- Fundamental parameters and conventions for the use of models, for example, the tidal system, and procedures are required.

The International Celestial Reference System (ICRS), based on a kinematic definition, is a quasi-inertial system. The ICRS provides the celestial foundation for the GGRS. The relationship between the ITRS and the ICRS is described by the Earth Orientation Parameters (EOP). The EOP are not only relevant as transformation parameters between the ITRS and the ICRS, but also for relating geometric and gravimetric quantities in a variety of ways.

Global Geodetic Reference Frame

The Global Geodetic Reference Frame (GGRF) is the realization of the Global Geodetic Reference System (GGRS), made possible through physical points on the Earth's surface, satellites in near-earth orbit, and celestial objects, along with parameters describing geometry and gravity over time.

The network of terrestrial points is global, with national and regional densification of the geodetic infrastructure. This network of GGRF stations typically comprises:

- fundamental geodetic observatories employing all⁴ space geodetic techniques co-located with gravimetric instruments, enabling the connection between X , W , and g ;
- other geodetic stations also including reference tide gauges, height datum points, and gravity measurement points co-located where possible with space geodetic instruments.

Fundamental geodetic observatories also include precise and stable time-keeping instruments and should be connected to time reference stations (in future using optical clocks for ΔW determination — relativistic geodesy) and gravity reference stations (equipped with absolute and superconducting gravimeters, see IAG Res. 2015 No. 2).

All GGRF stations must be:

- continuously operated, over the long-term, to ensure the stability of the GGRF;
- equipped with state-of-the-art observation technology so as to produce high quality measurements of geodetic quantities;
- continuously monitored to detect surface deformations of the Earth; and
- connected to height datums to precisely relate their geopotential differences for vertical datum unification.

The ITRS is realized by the International Terrestrial Reference Frame (ITRF) consisting of positions and time variations of network stations observed by space geodetic techniques such as VLBI, SLR, GNSS, and DORIS. Crucial for the integration of the different techniques are globally-distributed co-location sites with accurate local tie vectors.

The ICRF is a realization of the ICRS consisting of the positions of compact extragalactic objects, mostly quasars. These natural radio sources are sufficiently far away such that their expected proper motions are negligibly small. The ICRF is

¹ The following concept is based on H. Bruns' approach in *Die Figur der Erde* (1878).

² $W(\mathbf{X})$, $P\{\mathbf{X}, W\}$ or $P\{\mathbf{X}, W, \mathbf{g}\} = P\{\mathbf{X}, W, -\nabla W\}$, and $g = -\partial W / \partial H$

³ Gravity involves gravitation and centrifugal force.

⁴ The geometric observation techniques are currently: VLBI, SLR, GNSS, and DORIS.

realized by VLBI observations at terrestrial network stations.

Furthermore, the operability of the GGRF requires international standards and specifications for the exchange of measurements and products, and the use of harmonized models, parameters, and procedures.

For the realization and maintenance of the GGRF, an operational infrastructure in the form of international services and scientific organizations is needed. Currently the IAG Commissions and Services are responsible for the implementation of the UN Resolution on a Global Geodetic Reference Frame for Sustainable Development. The development of an integrated mechanism for the establishment and maintenance of the GGRF is one of the key GGOS goals. Hence the IAG will continue to play a leading role in defining the strategies and methodologies for the implementation of the GGRF.

Implementation Steps Towards the GGRF

The GGRF is an integrated geodetic reference frame, incorporating the ITRF and the ICRF, the future International Height Reference Frame (IHRF), and the new global absolute gravity network (IGSNn) according to IAG Resolutions 2015 No. 1 and No. 2, respectively.

The combination of the IHRF and the ITRF requires the Global Gravity Model (GGM). The GGM is derived by measurements from satellite gravity and altimetry missions, complemented with terrestrial gravity data. For the development of the IHRF, an IAG Joint Working Group will be established. To replace the International Gravity Standardization Net 1971 (IGSN71) with the IGSNn, a Working Group will define a geodetic gravity reference system based upon the international comparisons of absolute gravimeters. The globally-distributed reference stations of the IHRF and of the IGSNn, including the stations for international comparisons of absolute gravimeters, have to be linked to the fundamental geodetic observatories for co-location of gravity reference stations with space geodetic instruments.

With the resolution on a Global Geodetic Reference Frame for Sustainable Development the UN Member States are requested to:

- encourage, together with relevant international organizations, global cooperation in providing technical assistance, especially for capacity development in geodesy for developing countries;
- openly share geodetic data, standards, and conventions, through relevant national mechanisms and intergovernmental cooperation, and in coordination with the IAG;
- maintain, and improve their national geodetic infrastructures;
- engage in multilateral cooperation that addresses infrastructure gaps and duplications; and
- assist in the development of outreach programs that make the GGRF more visible and understandable to society.

The tasks for the IAG and its GGOS in the framework of the GGRF therefore are to:

- organize the IAG Services on a high scientific and technical level;
- support the development of geodetic technologies and products on the basis of open sharing of geodetic data, products, standards, and conventions;
- provide scientific leadership to all scientific organizations, national geodetic agencies, and Member States, on geodetic matters; and
- develop and improve theories and methodologies for the implementation of the GGRF.