

# **A Global Survey of Reference Frame Competency in terms of Education, Training and Capacity Building (ETCB): Results, Analysis and Update from 2021**

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## **SUMMARY**

Geodetic infrastructure, such as continually operating reference stations are a vital component of reference frames around the world. As such, a strong foundation of education, training and capacity building is essential for ensuring geodetic infrastructure can be established, maintained and operated correctly. This also ensures that geodetic data and information outputs can be processed, analysed and interpreted correctly.

In early 2018, the United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM) Subcommittee on Geodesy (SCoG) sought to facilitate a self-assessment of all member nations' sovereign capabilities to manage and maintain reference frames. The Subcommittee's working group on Education, Training and Capacity Building (ETCB) developed an online questionnaire seeking feedback specific to reference frame competency. Responses to this initial 2018 Survey were provided by 98 representatives of Member States and observers, across 65 Member States.

A previous paper presented the results of this initial 2018 Survey, offering a brief analysis of the findings, and outline summary of the issues. It also identified follow-on tasks for the UN-GGIM Subcommittee on Geodesy and its working groups to consider when defining the scope of the forthcoming Global Geodetic Centre of Excellence (GGCE).

This paper presents the preliminary results and analysis of the 2021 Survey, from 203 representatives from 101 Member States and observers, and which included greater focus on the regions, their current and required competencies, their formal educational backgrounds. This paper also reflects some of the recent changes to the SCoG and its Working Groups. Furthermore, linkages to the Subcommittee on Geodesy Infrastructure Survey will be identified when appropriate.

## **1. INTRODUCTION**

### **The Need for a Global Geodetic Reference Frame**

Geodesy is an important building block for sustainable development, the administration and management of land, as well as water and other natural resources interests. Looking forward, geodesy also has the potential to facilitate the critical access and alignment of future smart societies and their digital economies. In short, geodesy is playing an increasing role in the lives of people around the world, from finding directions using a smart phone to alleviating poverty and ensuring fresh water supplies. Because the Earth is in constant motion, an accurate point of reference is needed in every country for making measurements in the country. Geodesy

provides a very accurate and stable coordinate reference frame for the whole planet: a Global Geodetic Reference Frame (GGRF).

In February 2015, the United Nations (UN) General Assembly adopted the resolution “A Global Geodetic Reference Frame for Sustainable Development” – the first resolution recognizing the importance of a globally-coordinated and supported approach to geodesy, involving all UN Member States. Accordingly, the UN Committee of Experts on Global Geospatial Information Management (GGIM) Subcommittee on Geodesy (SCoG) is working towards developing an accurate and sustainable GGRF.

The GGRF Roadmap Annex 1 states that the GGRF is “*an authoritative, reliable, highly accurate, and global spatial referencing infrastructure. The GGRF includes the celestial and terrestrial reference frame products and Earth Orientation Parameters (EOPs) that connect them, the infrastructure used to create it, and the data, analysis, and product generation systems. The GGRF also includes gravimetric observations, products and height systems which underpin measurements of elevation.*”

### **The Motivation for Assessment of Reference Frame Competency**

In response to the GGRF General Assembly Resolution, the UN-GGIM SCoG developed a plan in 2017 to facilitate a self-assessment of all member states' sovereign capabilities to manage and maintain reference frames. At that time, the Education, Training, and Capacity Building (ETCB) Working Group was one of five working groups supporting the SCoG work towards realizing the GGRF Roadmap Implementation Plan.

As a component of the UN GGIM Subcommittee on Geodesy, the ETCB seeks to assess the current availability of education, training, and capacity building resources, identify gaps in capacity or other areas of need, and propose short- and long-term solutions to realize the full scientific and social benefit of the Global Geodetic Reference Frame. Wherever possible, elements of ETCB work that are in support of the United Nations Sustainable Development Goals (SDGs) and/or Sendai Framework for Disaster Risk Reduction (DRR) are identified.

The ETCB WG has developed a five-year strategy (see Appendix 1) as follows:

**Vision:** *Member States have the capability to develop and maintain state Global Geodetic Reference frames*

**Mission:** *The UN-GGIM Subcommittee on Geodesy working group on capacity building will coordinate and facilitate capacity building with a particular focus on regional needs and Member States with less capacity.*

## **2. THE FIRST GLOBAL REFERENCE FRAME COMPETENCY SURVEY – 2018**

The ETCB is tasked with assisting UN Member States build their capacity and expertise for the intuitive utilization and sustainable worldwide development of the GGRF, and consequently this assessment activity. It was hoped that the responses would provide sufficient insights to determine and collate:

- 1) Current competencies in Reference Frames (RF),
- 2) Future competencies and special interests that are required, and
- 3) Training needs of Member States.

Through its role to lead the development of the original questionnaire, the ETCB Working Group sought to summarise how the respondents perceived the capability of their national geodetic survey organisation (GSO) or agency in terms of defining, maintaining, and operating their national geodetic reference frame. Accordingly, the questionnaire was designed to assess Member State RF competency requirements and educational needs, and comprised of four Sections:

- 1) Information about the Responder and their affiliation,
- 2) Responder's assessment of current and future RF competency requirements of their Member State,
- 3) Member State training needs, and
- 4) Other information.

In considering the questionnaire, the ETCB recognised that UN Member States could have different competency requirements and that all Member States did not need to reach the same competency level. For example, a small island state might be a user of the GGRF and thus need competency in the use of GNSS and connection to the GGRF. A larger State providing geodetic infrastructure to support the development of the GGRF might need capability in VLBI and SLR etc. This led to the development of a matrix defining four levels of RF competency requirements (ETCB, 2018), of which an updated version can be seen in Table 3. It was also recognised that Member States could be at different levels in their current skill rating. Another question posed was to consider if there would be any regional differences in competency requirements, for example were the requirements in a region of predominantly small island nations be different from a continental region of Member States.

### **Summary and Final Recommendations – 2018**

As preparation for the reader, it is worth recapping the final recommendations from the 2018 Survey as in documented in (Keenan et al., 2020). This section affords a brief analysis of the findings, outlines a summary of the main issues and identifies a number of follow-on tasks for the SCoG and its working groups to consider when defining the scope of the forthcoming GGCE.

Based on the collective analysis and weighting of survey responses, four significant points must be considered to successfully build capacity for the GGRF:

- 1) There is a very strong interest or need to continue to build capacity for geodetic reference frame competency, especially in those developing countries with limited resources.
- 2) There is a very strong argument for the continued contribution of developed countries to support these developing countries at the global, regional and national level.
- 3) There is an increasing demand for a global facilitator of ETCB to help collate requests, arrange resources such as trainings, in-country workshops, technical reviews etc. This entity should also be responsible for ensuring stronger coordination and sustainable collaboration between those existing groups/organisations that currently provide these resources and could do so in the future.
- 4) Finally, this survey generated considerable objective feedback and insight for those forming the GGCE, its structural organisation, its objectives and the obligations that it must assume for it to truly deliver benefits and sustainable long-term impact

The overall challenge for geodetic organisations is to ensure that priority capacity building commences and becomes continuous; to do so, the following recommendations are given.

The following table summarises the full Recommendations derived from the GRFC Survey 2018 as featured in (Keenan et al., 2020).

ID	ACTION	DESCRIPTION	OWNER
1	Formal Distribution of ETCB RF Competency ‘2018/9’ Results	Send the results to i) GGIM-SCoG, and ii) all initial Respondents	SCoG WG-ETCB
2	Updated Survey for 2020	Extended to include the scope and questions relating to GGCE. Consider having in additional languages (i.e. French et al?) Distribution should be targeted to cover as many UN Member states as possible.	SCoG WG-ETCB together with WG OC
3	Strengthen the current Capacity Building through a centralised Facilitator	GGCE could become the central point for <i>organising and facilitating</i> the requests for, and provision of training courses, workshops, expert panels etc.	
4	Create a Global Competency Matrix for GGRF Resources and Funding	Create an accessible global database of resources (human & fiscal), assets, training and education materials, calendar of events, including an independent grading of member nations as below	GGCE, UN GGIM
5	Objective Independent Grading of Reference Frame Competencies for Member States	This could be carried out in a more formal objective manner, through the provision of dedicated evaluation forms, technical capability based on metrics, and then summarized in a Global Competency Matrix	SCoG / GGCE
6	Continue supporting and advocating the UN GGIM Integrated Geospatial Information Framework (IGIF) and its implementation	Provide assistance to member countries to develop country action / agency plans to address geodetic capacity development.	UN GGIM, SCoG WG-ETCB, FIG
7	Continue the provision of technical advice on modernisation of geodetic operations, infrastructure and systems.	Actively participate in events, workshops, seminars, and meetings on specific operational geodesy topics such as GNSS CORS, reference frame / datum, and data management	UN GGIM, SCoG WG-ETCB, FIG, IAG, UNOOSA

Table 1 – Recommendations from the 2018 Survey for ongoing ETCB activities on raising the level of Global Reference Frames Competency

As Item #2 in Table 1, an updated survey was recommended to gain further insights on regional capabilities and aspirational needs, along with a more targeted participation from the regions of South America and Africa.

### 3. THE SECOND GLOBAL REFERENCE FRAME COMPETENCY SURVEY – 2021

This paper presents the preliminary results and analysis of the 2021 Survey (and is named as the Global Reference Frame Competency Survey – 2021 (GRFCS2021)) which included greater focus on the feedbacks across region, in terms of their current and required competencies, their formal educational backgrounds and a more targeted distribution of the

survey as a means of garnering more responses from the Regions. This paper also reflects some of the recent changes to the SCoG and its Working Groups in March 2023.

NAME	DATE	FEATURES
<b>Global Reference Frame Competency Survey 2018</b>	2018-19	Initial Survey
<b>Global Reference Frame Competency Survey 2021</b>	2021-22	Additional questions around: regional needs, current competencies and formal qualifications; required competencies and skill sets.

Table 2 – Metadata of the Two Global Reference France Competency Surveys from 2018 and 2021

The 2018 Survey asked respondents to self-evaluate their current and target competency level, based on a 4-level “[Geodetic] Competency Level” (CL) matrix designed by the ETCB Working Group. GRFCS2021 expanded this rubric internally to the survey administration system (Qualtrix-based) with strategic and targeted questions focusing on key competencies and required skills. Questions were designed in collaboration with geodesy educators to improve transparency of respondent current skills as well as to better understand skills would be necessary/required to maintain/advance their reference frame competency.

Ultimately, the questions implicitly included these criteria (formerly transparent to the respondent through the 4-level rubric) in order to indirectly determine the CL of each country. (For example: instead of asking "What is your current competency level?", we asked if the country has a CORS network, if they can perform high-end GNSS analyses, if they monitor Earth dynamics, etc).

The second Survey was hosted online starting in February 2021, and was open for total period of 14 months (ETCB, 2021). Feedback from each section of the 2021 Survey was gathered, analysed and presented in summary form with noteworthy findings and observations, along with a set of initial proposals – all the time noting that these are only preliminary findings.

SURVEY	DURATION (months)	NUMBER OF RESPONSES	NUMBER OF MEMBER STATES REPRESENTED
<b>2018</b>	22	98	65
<b>2021</b>	14	203	101
<b>Increase # (%)</b>	N/A	+105 (107%)	+36 (55%)

Table 3 – Summary of Number of Respondents and Member States completing the two ETCB RF Competency Surveys from 2018 and 2021

**Preliminary Results of the 2021 Survey**

This section provides information about the respondents and their affiliations. A total of 203 responses were received from a total of 101 Member States in the 14 months since the first posting of the survey. Figure 1 shows the Member States that responded to the survey, and Figure 2 presents the number of responses submitted by each respondent. The breakdown of the respondents in terms of their organisation type, affiliation and role can be found in Table 1 and Table 2.

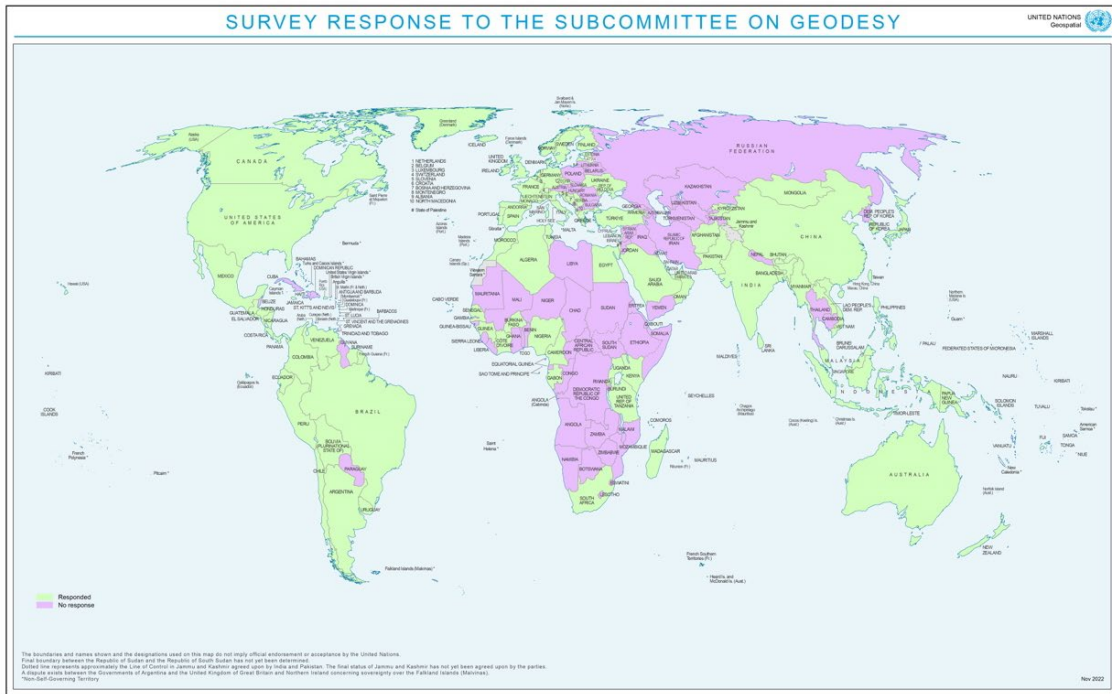


Figure 1 – Member States that responded the 2021 ETCB RF Competency Survey (shown in green)

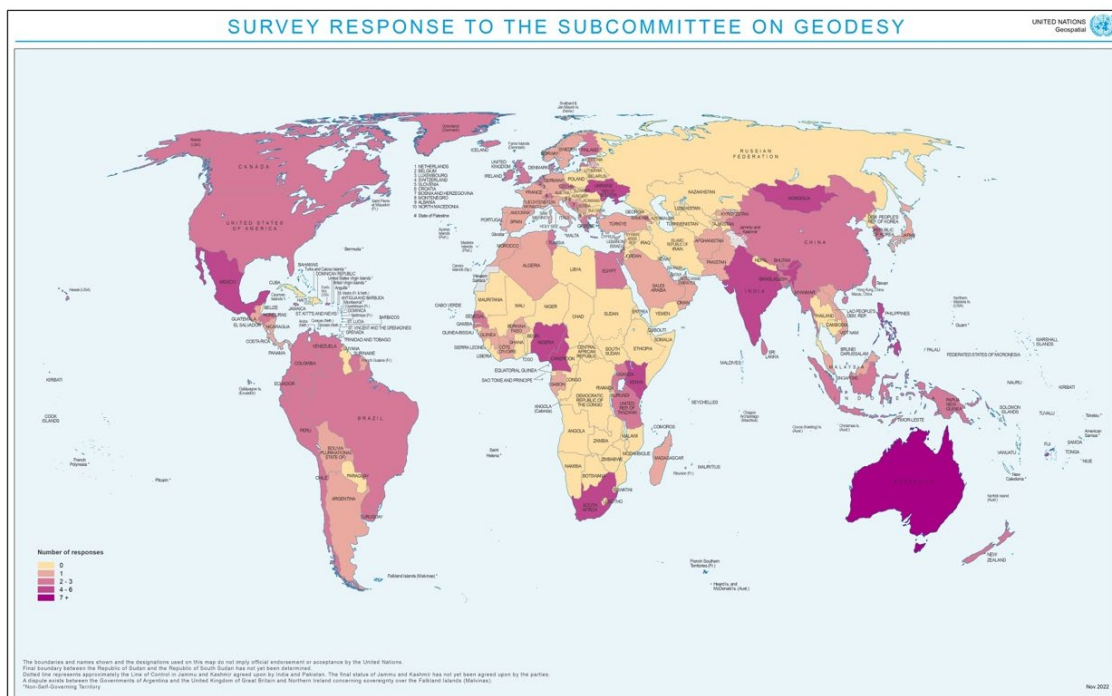


Figure 2 – Number of Responses per Member State to the 2021 ETCB RF Competency Survey (lightest colour equals zero response, darker shades indicate multiple responses)

In terms of affiliation, at least 55% were from UN-GGIM delegations (cf. Table 4). Government agencies made up approximately 80% of identified respondents, with 9% from academic organisations, around 8% from the private sector and 2% from non-governmental organizations and UN specialized agencies (cf. Table 5).

AFFILIATION	COUNT (%)
No official affiliation / Other	90 (44%)
Member of UN-GGIM Member State delegation	72 (35%)
Head of UN-GGIM Member State delegation	18 (9%)
Member of UN-GGIM UN System and related organizations delegation	8 (4%)
Member of UN-GGIM Intergovernmental organization delegation	7 (4%)
Member of UN-GGIM Non-governmental organization delegation	5 (2%)
Member of UN-GGIM Non-member State delegation	3 (1%)
<b>Total</b>	<b>203</b>

Table 4 – Breakdown of Respondents by Affiliation (expressed as count and percentage)

ORGANISATION / AGENCY	COUNT (%)
Governmental (National Mapping Agency/Cadastre)	61 (30%)
Government (National Survey and Mapping (Cartographic))	61 (30%)
Academic (University, Research Institute)	18 (9%)
Governmental (Other)	16 (8%)
Government (General)	15 (7.5%)
Private Sector (Mapping or Geospatial Information)	6 (3%)
Governmental (Geospatial Intelligence)	3 (1.5%)
Private Sector (Engineering Services or Consulting)	3 (1.5%)
Governmental (Military)	3 (1.5%)
Private Sector (Geodetic Equipment or Software)	3 (1.5%)
Private Sector (Other)	3 (1.5%)
Non-governmental Organization (NGO)	2 (1%)
Government (National Hydrographic Organization)	2 (1%)
UN Specialized Agency	2 (1%)
Government (Space Agency)	2 (1%)
Academic (Vocational Training)	1 (0.5%)
Regional Organization (including regional NGOs)	1 (0.5%)
Governmental (Other Scientific Administration or Agency)	1 (0.5%)
<b>Total</b>	<b>203</b>

Table 5 – Breakdown of Respondents by Organisation / Agency Type (expressed as count and percentage)

Respondents held a wide range of positions with a total of 55 different titles being provided, covering a comprehensive range of experiences and responsibilities within their respective organisations. Several countries were able to provide additional feedback from multiple respondents, which helps to give more emphasis and spread across the relevant competencies.

This section covers the results for respondent-provided assessment of current and future RF competency requirements of their Member State. By assessing these, the ETCB expected to be suitably informed to focus their efforts on helping build targeted training and developing competency that will benefit each Member State, as well as filling critical needs for the GGRF.

The following figures around reference frames and GNSS CORS are based on subsets of information collected in the 2021 Survey. Note that these figures are based on the ‘Total Number of Responses’. It may be considered to provide a complementary analysis examining outcomes ‘Per Member State’, which would require further work since many member states provided multiple answers that are sometimes contradictory.

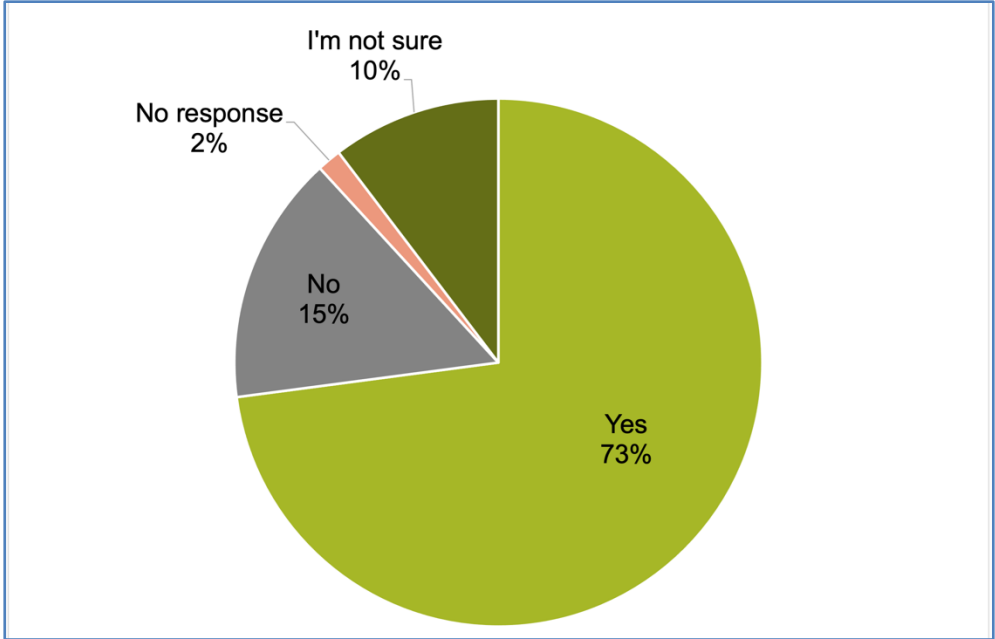


Figure 3 – Responses to the question “Is there a geocentric national reference frame that is connected to ITRF implemented in your Member State?” (as % of number of responses)

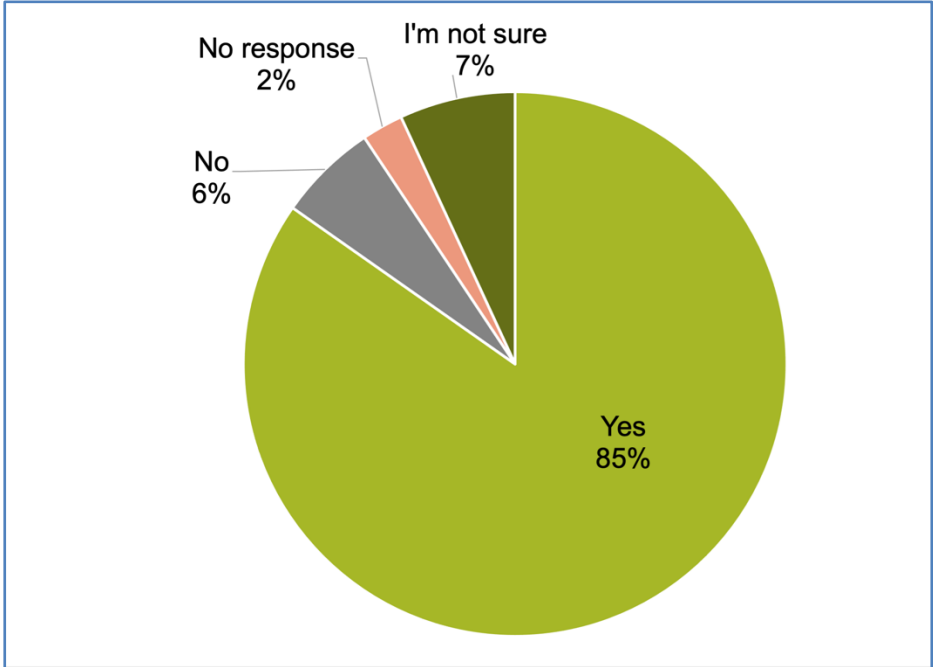


Figure 4 – Responses to the question “Is there a vertical datum in your Member State?” (as % of number of responses)



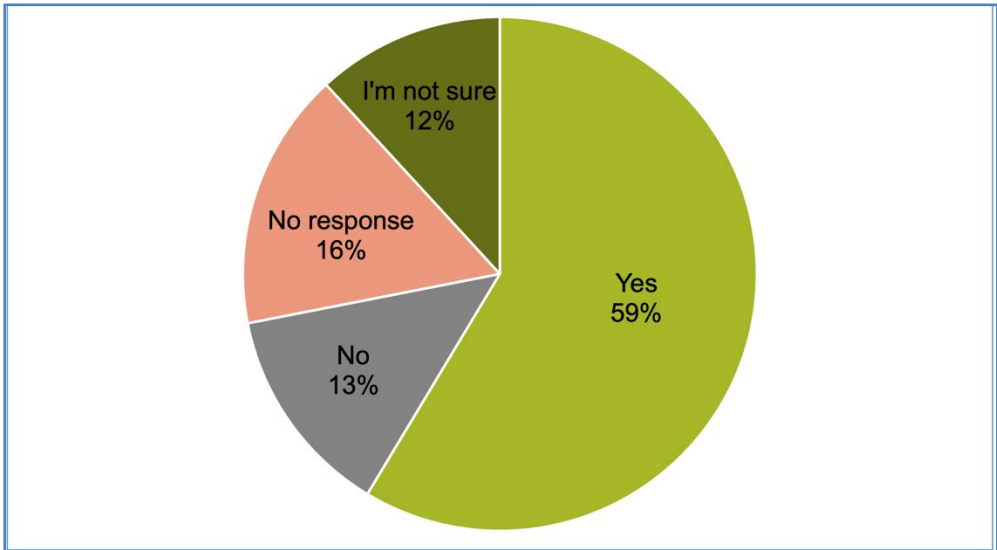


Figure 5 – Responses to the question “Does your Member State have the capability to build new and maintain its current GNSS CORS stations?” (as % of number of responses)

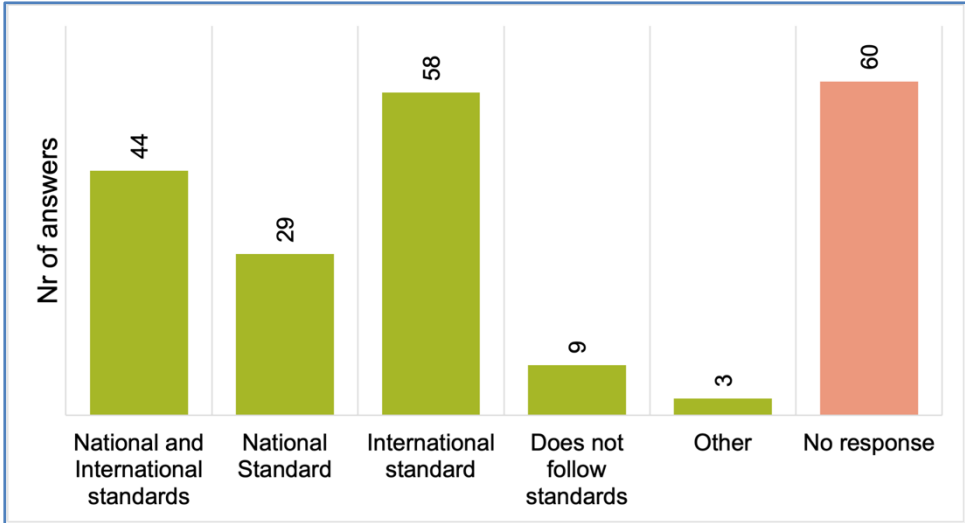


Figure 6 – Types of guidelines/standards that Member States follow when building a CORS (in number of responses)

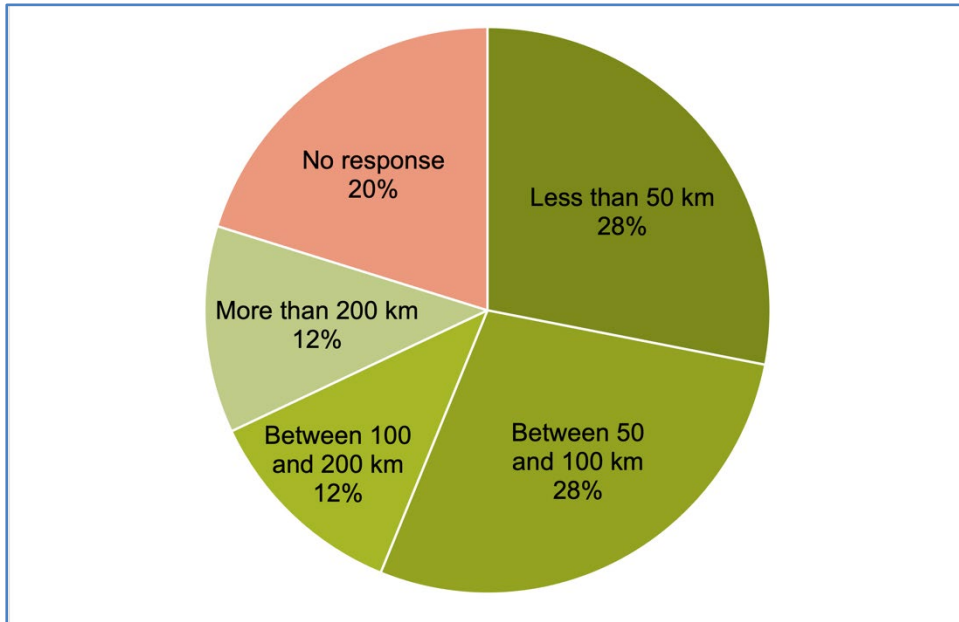


Figure 7 – Average distance between GNSS CORS (as % of number of responses)

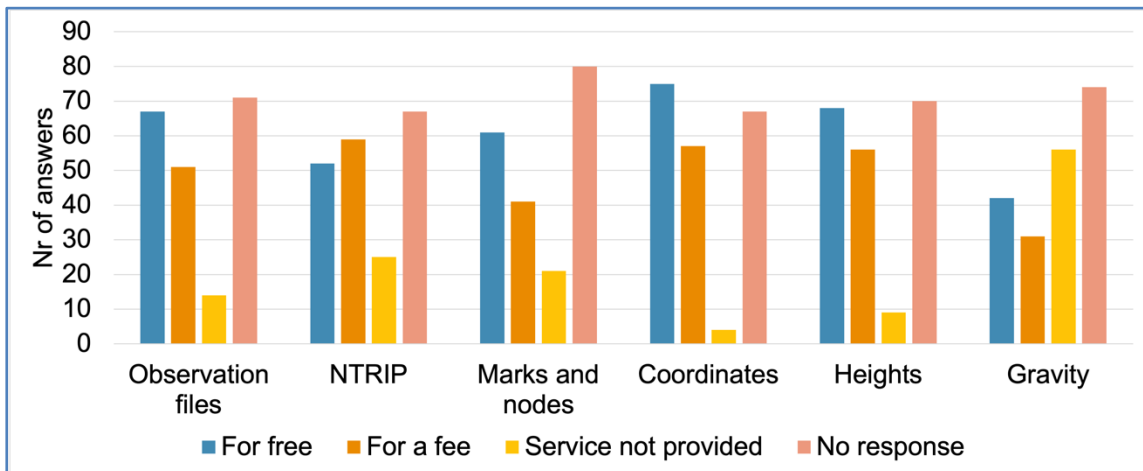


Figure 8 – Types of Geodetic and Positioning Services offered by the Member States and their cost (in number of responses)

A deeper analysis could be carried out to gain more insights around some responses. For example: for the case of the NTRIP Service, Australia provided 10 responses: 4 stating NTRIP is offered for free, 1 that NTRIP is offered for a fee, 2 stating Australia does not provide NTRIP services, with 3 not responding. Therefore, if plots should be produced with 1 answer per Member State, a more thorough analysis is required to determine the actual situation. For clarification, NTRIP Services are offered in Australia both for free, and for a fee—depending on whether a public or private NTRIP services are accessed respectively. Such an example highlights the variance of responses from each and every Member state, and raises the question, should there be further granularity sought on these questions in a future survey?

## 4. PRELIMINARY FINDINGS – 2021

Before discussing the following survey findings, it is necessary to state some caveats about the survey results.

- **Timing** – the window for responding to this survey was just over a year, so the status quo in some GSOs may have changed during this time.
- **Missing Responses** – in the situation where responses were not submitted for sections in the questionnaire, the term 'No Response' has been included so that a correct statistical proportion is given in the results.
- **Competency Level (CL) Grading Subjectivity** – these are self-proclaimed competency evaluations, open to the subjectivity of each respondent, their overall knowledge, awareness and experiences; these responses may not have accurately reflected the true situation of actual competency levels.
- **Agency Bias** – the type of agency completing the questionnaire may impact on the answers provided. This was highlighted by the variation in responses from countries where multiple responses were received from different agencies.
- **Completion** – there are a total of 195 Member States, all with the need of GRF, however this 2021 Survey was only answered by 101 Member States. Greater participation in this (or a follow-on) survey may occur as and when the GGCE is fully operational and can facilitate higher completion rates..

### Needs around Capacity and Capability

The following section is a preliminary view of the 2021 Survey results and will be subject to further analysis and evaluation from the ETCD Working Group. Nevertheless, from initial inspection of the responses received, it is apparent the intent and messages from the respondents are reasonably similar to those of the previous 2018 Survey. Without prejudice, this generally suggests the present-day training or capacity and capability (CC) needs are consistent with the Geodetic Competency Level matrix.

The 2021 results, similar to those from 2018, revealed the high demand for fundamental or specialist geodetic knowledge in the technical and theoretical aspects; including the establishment, maintenance or modernisation of the necessary infrastructure and systems; and the need to improve or develop the application or implementation of such competencies. The competencies and activities that were significant and prioritised by the respondents were as follows:

- GNSS – CORS networks, measurements / observations, analysis, data management and distribution,
- Reference frame and datum modernisation, determination and realisation,
- Vertical datum and height surface measurement and analysis,
- Gravity and geoid modelling, and
- Measuring and monitoring the dynamics and deformations of the Earth's surface.

The initial evaluation of the 2021 Survey responses highlighted the emerging interest and need for CC development in non-core related geodetic competencies as follows.

- Harmonising local height systems to a global or regional vertical reference frame to support the integration of various height surfaces in the built environment and their practical applications in land administration/management.
- Geodetic portals or mechanisms to facilitate easy access and sharing of data or knowledge on observation techniques, processing, analysis, publishing, and data management.
- Programming / script writing for geodetic processing and analysis to facilitate interoperability and modernisation of workflows for geodetic observations into IT infrastructure and systems, and the use of machine learning (ML) and artificial intelligence (AI) .
- IT administration management to utilise web/internet-based technologies, open source options, database, and integrated land/water information systems.
- Legal frameworks and policy development (regulation/standards/practices/guides)
- Organisational and people management
- Marketing and promoting the value and importance of integrating geodetic information with both the non-traditional and broader geospatial information management community.

### **Challenges for Capacity and Capability**

The preliminary analysis suggests capacity and capability (CC) challenges raised in the 2018 Survey were again confirmed in the 2021 Survey. An appraisal of the main issues, challenges and barriers raised by GSOs are classified and summarised under two conceptual themes.

#### 1) Institutional, Governance and Leadership

- Lack of political and administrative support from decision makers, caused by a lack of understanding of the importance and value of geodesy (including datums, reference frames, positioning) in measuring, monitoring or obtaining social and economic objectives.
- Geodesy is neither a priority capability nor favoured in organisations (especially governments), and consequently there is a lack of budget and resources (particularly financial and personnel) for geodetic operations, equipment/infrastructure, IT, communications, as well as capability and capacity development programs.
- Missing strategic plan and implementation framework providing a co-ordinated approach to improve capacity and sustain capability.
- Organisational planning is often not aligned with national or country objectives.
- For some regions, there are no mechanisms and frameworks enabling the collaboration of efforts, avoidance of duplication, exchange of technical knowledge, and the provision of training for geodetic CC development.
- There is a lack of understanding of formal legal and / or policy frameworks (as well as a lack of motivation to modernise) on the administration of data (especially sharing); recognition of standards / practices and guides; supporting transparency, accountability to the community; the process of evidence-based decision making; and the need for reliable IT / communications networks.
- Shifting paradigms and changing organisational work culture, to become less autocratic and more aware of the potential opportunities in collaborating and co-operating with other organisation (or neighbouring) countries to achieve CC objectives.

## Knowledge, Learning, People

- A lack and decline of qualified experienced geodesists (as well as educators and trainers) at various levels and within institutions such as government, academia, operational, and scientific.
- A lack of interest in geodesy and geosciences in general amongst young land professionals and scientists.
- Age profile and gap of the experienced and non-experienced in geodetic community, in some cases, aging and growing wider respectively.
- The lack of appropriate education/training institutions and facilities that develop the basics of surveying and geospatial information, as well as the core competency levels of geodesy.
- No system or framework to utilise or support the “experts or specialists” and “trainers or educators” available to provide CC development on core competencies.
- Emerging geodetic related agencies rely on international experts volunteering their assistance beyond their current role, and thus their ongoing availability is due to the goodwill of them4r/their employer which can be limited/restricted and is inherently unsustainable.
- Lack of adequate needs-based assessment of CC requirements thus leading to inappropriate CC development strategies, pathways and succession plans.
- Insufficient provision and allocation of resources into geodetic CC development.
- Agencies and countries learning to and having the willingness to collaborate and co-operate on CC development initiatives.

## **Solutions in Capacity and Capability**

As with earlier sections of this paper, the 2021 and 2018 responses have provided comparable suggestions and pathways to resolving CC issues and challenges. Consequently, the following solutions are based on a combined review and assessment of the responses, and includes the experiences and knowledge of the ETCD Work Group, who have been engaging and working with countries on CC development, along with other key stakeholders.

Some first solutions:

- Identify “champions” who can influence policy to act on geodesy needs.
- Draft a geodetic competency resource mobilization strategy.
- Identify or create resources for a selection of target audiences (personas) that facilitate advocacy and access to information about the GGRF and its benefits.
- Building engagement with universities and higher education establishments.
- Draft agreements amongst proactive / competent educational institutions; similarly, establish MoUs from development partners/agencies to support positions at these institutions.

The main solutions to develop geodetic CC have been segmented into the following categories, and without any prioritisation:

### **Education/Training:**

- Promote surveying, geospatial information and geosciences at the secondary level of education as choice professional or scientific careers.

- Streamline the curriculum at tertiary level education to have a clear pathway for geodesy with particular reference to the fundamentals of surveying, i.e. competencies prior to Level 1.
- Develop a Core Geodetic Competency strategy and framework to support, generate, resource and implement training on the following core geodetic competencies:
  - Determination and computation of Reference Frame parameters.
  - Height unification and modernisation.
  - Geoid determination.
  - Geodetic network adjustments and transformation parameters derivation.
  - Geodetic data management fundamentals and planning.
  - Establishing, operating and maintaining a GNSS CORS network.
  - Understanding the techniques/measurements from GNSS, VLBI, SLR, DORIS, Gravity and InSAR.
  - Monitoring and measuring the dynamics and deformation of the Earth; dynamic reference frames and datums; implications and applications; time-dependent calculations and models.
- Develop a strategy and framework on non-Core Geodetic Competencies to support, generate, resource and implement training in the following:
  - Determination and practical applications of harmonised local height systems, referenced to regional vertical datums, with height surfaces for the built environment, land administration/management and others.
  - Creation of web-based portals and mechanisms to access and exchange geodetic data, and share knowledge and experiences on observation techniques, processing, analysis, publishing, data management, strategies and reference materials.
  - Programming / script writing for geodetic work processes, such as processing and analysis of data; and development of platforms to facilitate interoperability of geodetic information into IT infrastructure and systems.
  - IT administration management capacity and capability to effectively use web-based technologies, open-source options, database, and integrated land / water information systems.
  - Establishment/modernisation of legal frameworks and policy development to support and advance geodetic CC programs.
  - Organisational planning, implementation, and monitoring.
  - Management of people, including the execution of “organisational cultural” change, and influential engagement and communication with stakeholders.
  - Skillsets for marketing and promoting the value of geodesy, and the importance of integrating geodetic information, with both the non-traditional and broader geospatial information management community, to all stakeholders, especially decision makers.
  - Interpreting and implementing the United Nations Integrated Geospatial Information Framework (UN-IGIF).

### **Institutional / Organisational**

- Greater recognition and advocacy of geodesy and its benefits to all stakeholders and the greater community.

- Scientific partners to make clearer statements on the requirements to becoming a regional geodetic data repository or analysis centre; and understanding the operations, services and products.
- Creation and support of an operational framework that will centralise CC development and support regional operations to administer resourcing, investment, training, scholarships, grants etc. from internal and external sources.
- Professional, scientific, academic, donor, and funding agencies/organisations to provide materials which clearly identify their role and responsibilities in CC development such that geodetic organisations are aware of the options available, and associated processes: i.e. what are they, how to access, understanding the eligibility criteria and requirements, and the process to apply.
- Development of strategies to encourage more support, effort and assistance from those geodetic organisations who are at Level 3 and 4 (of the Geodetic Competency Level matrix) to those at Level 1 and 2 (primarily Knowledge Transfer).
- Through a central CC development agency (CCDA) improve the coordination by the agencies who have possessed the required “levels” and the global/regional bodies operating in the professional, scientific, funding, and donor spectrum.
- Geodetic organisations should commence or develop a capacity and capability development plan (CCDP) and consider the following:
  - Seek national support and ownership to drive the planning and implementation of the CCDP.
  - CCDP to be led by both organisational and national leaders who are empowered and willing to change structures and processes, to improve organisational performance and overall organisational efficiency and effectiveness.
  - A common understanding of the CCDP purpose, scope and objectives, and agreement on the end outcomes.
  - An objective assessment process (inclusive and diverse) to reach a consensus view of CCDP needs, recommendations, and activities.
  - Adapting a capacity development “participatory” approach which suits the organisational environment and accommodates circumstances of other likeminded organisations (or nations) involved.
  - Clarity of CCDP roles and responsibilities including who is accountable for implementing, evaluating, and delivering CCDP activity.
  - National CCDP planning, and budgeting (includes resourcing) should be prepared and incorporated as part of the initial programme development to support modernisation.
  - Integration of “realistic” and incremental (phased) CCDPs with existing organisational (and national) plans and strategies, rather than being seen as separate programmes.
  - Include participating donors, development partners, and stakeholders at the planning stage, to ensure coordination of various capacity development initiatives, cost sharing, and resource sharing.
  - Through a structured evaluation mechanism, regularly review and update the CCDP to monitor progress and make necessary changes.
  - On-going and transparent communications and collaboration with “all stakeholders” regarding the CCDP and its progress.

## **Sharing and Collaboration**

- Geodetic organisations should enter into agreements to share and exchange both resources and data across borders where possible.
- Develop pathways, structures, frameworks and roadmaps that facilitate greater collaboration amongst member countries, academic institutions (including the scientific and research community) and the commercial sector, to deliver pragmatic and fit-for-purpose solutions.
- Facilitate greater collaboration and engagement, and investigate alternate sources of resources, in particular the private sector and independent experts who can assist.
- Develop strategies and opportunities for regional training or exchange of information to attain a consistent approach and community spirit.
- Implement a collaborative regional approach to developing geodetic CC using the successful pathways taken by numerous countries and territories in the Pacific as guides.
- Greater collaboration amongst the geodetic community and the academic sector to develop programs specifically for CC development, and agreements for participation of developing countries.
- Increased inclusion of the commercial or manufacturing sector of surveying, geodesy and geospatial information.
- Examine sustainable ways to “bridge” the knowledge gap and digital divide, between developed and developing geodetic organisations or countries, as well as those in transition.

## **CCDP needs to become part of an IGIF-based CAP (Country Action Plan)**

Based on this analysis, it is evident more assistance and coordination is necessary to articulate, integrate and connect geodetic organizational strategies with the requirements of the GGRF Roadmap. The strategic pathways of the IGIF, especially the Capacity and Education Strategic Pathway, will serve as an important touchstone to ensure resourcing for a meaningful and relevant multi-faceted CAP.

CCDPs should align or harmonize their organizational plans with the vocabulary and template of the IGIF, to ensure sufficient and appropriate representation of geodesy in IGIF CAP. Furthermore, these plans should also note the value of aligning with the GGRF Road Map and Road Map Implementation Plan. Incorporating the IGIF guidance, vocabulary, and templates will ensure that relevant GGRF documents, plans, and other information supporting reference frame capacity are made findable and accessible to geodetic stakeholders, and facilitate interoperability of geodetic capacity and capability resources as well as infrastructure.

One further observation was that most organisations would benefit from receiving an independent holistic evaluation of their current competencies with specific objective focus on achieving their target competencies with respect to their strategic roadmap and vision.



## 5. REALISING THE GGCE

In August 2019, Member States of the UN-GGIM commended the SCoG on the revised proposal to establish a global geodetic centre of excellence (GGCE) under the auspices of the United Nations to help address the critical gaps within the GGRF.

The proposed objectives of the GGCE are to bring about:

- The development and sustainability of geodetic infrastructure and analysis in Member States through enhanced global cooperation to ensure an accurate, sustainable and accessible GGRF to which regional and national Member State reference frames can be aligned.
- Making geodetic data Findable, Accessible, Interoperable and Reusable (FAIR) so it can be shared globally and used to improve decision-making.
- Meeting Member State long-term geodesy training and capacity development needs by assessing requirements and developing a capacity building program based on UN Development Program (DP) guidelines.
- Improved communications and outreach to describe why geodesy is important, in particular to policymakers.

In March 2023 [UN GGIM, 2023], the GGCE was officially opened in Bonn, Germany, and at the time of writing, is actively recruiting technical staff to operate the centre. The GGCE will act as an operational hub to support the objectives of UN-GGIM and the Subcommittee on Geodesy, with three initial thematic priorities:

- Enhancing global cooperation,
- Providing operational coordination, and
- Providing technical assistance and capacity building.

The SCoG works within the guidance of the GGRF Roadmap Implementation Plan and the position paper to define the appropriate governance arrangements for the GGRF. In alignment with the Roadmap structure and the recent governance changes, work is organised into three focus groups, with each assigned one of the key issue categories of the Roadmap: Geodetic Infrastructure (GI), Global Geodesy Needs (NA), and Education, Training and Capability Development (ETCD).

Consequently, given this development intention around the GGCE, it was clear that feedback gathered by the ETCB surveys would be extremely valuable in terms of reflecting an objective large-scale survey of the current status quo of RF competencies amongst UN Member States. It is hoped that the findings gained from the two Surveys will provide suitable motivation, material, impetus, for the GGCE in its operational roles.

## 6. MOVING FORWARD

The UN-GGIM SCoG, together with the global geodetic community, can overcome the common challenges and accelerate to higher levels of RF competency by facilitating the necessary mix of training, exposure, collaboration and knowledge transfer.

As quoted earlier during one of the objectives for the GGCE – ‘Making geodetic data Findable, Accessible, Interoperable and Reusable (FAIR) ...’; the authors feel that the GGCE should ensure that training and education be treated in a similar manner with the following objective:

- Making **education, training and capacity development** Findable, Accessible, Interoperable and Reusable (FAIR) so it can be shared globally and used to improve decision-making.

Ultimately, it is believed that the GGCE is best positioned to deliver, implement and facilitate an enhanced, fit-for-purpose and globally sustainable capacity building initiative for ongoing GGRF education and training, with support from the working groups and partner organisations.

A more detailed analysis will be completed in the coming months with the intention for this report to be formally presented to both the UN GGIM SCoG and the GGCE, possibly at a future joint event. Furthermore, linkages to the Subcommittee on Geodesy Infrastructure Survey will be identified when appropriate.

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## 11. APPENDIX 1

The following table shows the common competency requirements deemed necessary for Reference Frames, categorised into four levels, with an increasing level of competence, knowledge and know-how per level. Note that this is an ‘evolving’ competency matrix based on questionnaire responses, and national organisation status reports from around the world.

This matrix provides government survey organisations (GSOs) with insight to descriptions of the skills, experience and knowledge required to build and operate modern geospatial reference systems and infrastructures (GRSI), along with training and education requirements, and possible sources to provide the relevant capability (Sarib, 2020).

LEVEL	COMPETENCY REQUIREMENTS	TRAINING PROVIDED BY	COMMENTS
1	Basic understanding of: <ul style="list-style-type: none"> <li>GNSS</li> <li>Reference frames, including geoid models, vertical and horizontal datums</li> <li>Geospatial information integration and interoperability</li> </ul>	<ul style="list-style-type: none"> <li>Educational institutions – universities and polytechnics</li> <li>Government geodetic, survey and mapping agency</li> <li>Private companies</li> <li>Global Geodetic Centre of Excellence (GGCE) member</li> </ul>	Countries that might have one CORS and maintain a traditional geodetic network of reference marks.
2	The above plus knowledge of: <ul style="list-style-type: none"> <li>Constructing, building and running a small CORS network</li> <li>GNSS processing using commercial / consumer off-the-shelf software</li> <li>Least squares processing and provision of datum access</li> <li>Geoid models, determinations, precision, and basic implementation</li> <li>Implementation of a vertical datum including use of geoid models</li> </ul>	<ul style="list-style-type: none"> <li>Educational institutions – universities and polytechnics</li> <li>UN-GGIM Geodesy Capacity Group</li> <li>FIG / IAG</li> <li>Government geodetic, survey and mapping agency</li> <li>Private companies</li> <li>GGCE member</li> </ul>	Countries with small CORS network and those who adopt global reference frames for their nation reference frames.
3	The above plus high knowledge of: <ul style="list-style-type: none"> <li>Implementing and running large CORS networks</li> <li>High-end GNSS processing and datum access</li> <li>Geoid model computation and implementation into a vertical datums</li> <li>Monitoring earth dynamics and including in datum realization</li> <li>Geodetic database management</li> </ul>	<ul style="list-style-type: none"> <li>Specialized courses – e.g. geoid school</li> <li>UN-GGIM Geodesy Capacity Group</li> <li>IAG / FIG</li> <li>Government geodetic, survey and mapping agency</li> <li>Private companies</li> <li>GGCE member</li> </ul>	Countries with a more extensive CORS and developing their own specialized national and vertical datum.
4	The above plus expert knowledge of: <ul style="list-style-type: none"> <li>Reference frame determination and computation</li> <li>High-end GNSS analysis and processing</li> <li>SLR including analysis and processing</li> <li>VLBI including analysis and processing</li> <li>Gravity collection, processing and geoid determination</li> <li>Analysis centre – combining various geodetic techniques to determine reference frame parameters</li> </ul>	<ul style="list-style-type: none"> <li>IAG</li> <li>Specialist training courses run by space agencies, national mapping agencies, and others – e.g. on VLBI or SLR</li> <li>Private companies</li> <li>GGCE member</li> <li>Specialized software training courses – e.g. Bernese and GipsyX</li> </ul>	Countries engaged in Global Reference Frame determination and Geodesy Science.

	<ul style="list-style-type: none"> <li>Use of other potential geodetic techniques – e.g. DORIS and InSAR</li> </ul>		
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Table 6 – Matrix of Predefined Levels of Reference Frame Competency requirements first mentioned in (ETCB (2018)) and also used for the 2021 Survey without modification



**Vision**

Member States have the capability to develop and maintain state Global Geodetic Reference frames

**Mission**

The UN-GGIM Subcommittee on Geodesy's working group on Capacity Development will coordinate and facilitate capacity building with particular focus on regional needs and those Member States with less capacity.

**Goals**

Development organisations invest in national and regional geodetic capacity building to ensure efficient access to, and utilisation of, the GGRF in developing countries

Member States, in cooperation with the IAG, FIG and other organisations, establish a global geodetic technical assistance program.

Member States, which have the capacity, assist Member States with less capacity to build sufficient geodetic capacity to efficiently and accurately access and utilise the GGRF

Member States take actions to ensure educational and research institutions recognise the importance of geodetic science, as well as increase the number and availability of geodetic courses in other associated degrees

Member States openly share all geodetic skills.

**Activities**

*Develop a capacity building programme that ensures balanced regional representation*

- Encourage regional participation on the UNGGIM subcommittee on Geodesy
- Work with regional groups to determine training needs at regional levels

*Prepare and implement an annual openly available training programme*

- Compile and promote the annual training programme
- Ensure training material from workshops is made readily and openly available
- Implement a policy of open availability for all materials and recordings from training programs/classes

*Prepare and implement an annual openly available training programme that includes workshops and the provision of technical material*

- Compile and promote the annual training programme
- Ensure training material from workshops is made readily and openly available
- Implement a policy of open availability for all materials and recordings from training programs/classes

*Provide a mechanism to develop and disseminate technical material*

- Implement an ETCB web page as a sub-page of the GGIM Subcommittee on Geodesy
- Work with the GGRF WG C and Communications Focus to ensure optimal development and delivery of educational advocacy materials

*state participation in capacity building*

- Promote the capacity building programme through geodesy conferences and meetings, and the UN GGIM Web site

*Incentivize stakeholder participation and sponsorship*

*Maintain close contact with national and international agencies and organizations, who may provide funding, advocacy, or other technical support for training and capacity building*

*Using GGRFwide and approved metrics, assess the geodesy training needs and capacities to assist or contribute, of each member state*

- Carry out a training needs analysis for all member states.
- Assess any surplus or abundant resources, and the ability to share these
- Establish a priority list of short term and longer term training needs.

*Work with the IAG and FIG to establish and run technical workshops in, and with a focus on, developing countries*

- Develop a programme of training workshops
- Develop a standing scientific organizing committee
- Provide a centralised list of technical workshops and training activities
- Provide access to training material
- Establish training agreements with key stakeholders

*Work with geodesy technical research institutes to develop and enhance geodesy training*

- Establish minimum training for a set of standardized training spanning infrastructure, and long-term sustainability
- Established training resource centres of expertise

- Work with stakeholders to ensure cooperation and benefits for the strategy
- Establish centres of training expertise and capability
- Work with national agencies and international organizations to develop internationally recognized certification programs

**Measures of Success**

- All Member States have appropriate geodetic capacity to underpin the realisation of the sustainable development goals.
- Geodetic education, skills, and capabilities are continuously developed and available to all Member States sufficient to underpin both GGRF and Member State sustainability and development.
- A global geodetic technical assistance program exists.
- Member States wishing to contribute to GGRF are supported through provision of technical assistance, educational programs, and coaching. Targeted capability development may be required to allow for continuity of skills over time.
- Continuous improvement of geodetic expertise in developing and developed Member States, through participation in, and open sharing of geodetic skills through conferences meetings and educational programs.
- Capability transfer occurs between existing experts and those emerging in this area.
- Sufficient resources are allocated to research programs promoting and underpinning GGRF development.