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

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Key words: reference frames, geodetic competency, capability development.

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, also their data and information outputs can be processed, analysed and interpreted correctly.

In early 2018, the UN-GGIM Subcommittee on Geodesy 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 developed an online Questionnaire seeking feedback specific to Reference Frame Competency. Response to this survey so far, has been provided by ninety-eight representatives of Member States and observers across the world.

This paper presents the results of this survey, and offers a brief analysis of the findings, outlines a summary of the issues and identifies a number of 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. Furthermore, linkages to the Subcommittee on Geodesy Infrastructure Survey will be identified when appropriate.

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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 the future of 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.

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 Global Geospatial Information Management (GGIM) Subcommittee on Geodesy (SCoG) is working towards developing an accurate and sustainable Global Geodetic Reference Frame (GGRF).

The GGRF Roadmap 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 Subcommittee on Geodesy 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, work is organised into five focus groups, with each assigned one of the key issue categories of the Roadmap: geodetic infrastructure; data sharing, policy, standards and conventions; education, training and capacity building; communications and outreach; and governance.

The Motivation of Reference Frame Competency

In preparation for the GGRF, the UN-GGIM SCoG sought, to facilitate a self-assessment of all member nations' sovereign capabilities to manage and maintain reference frames. The Education, Training, and Capacity Building (ETCB) Working Group is one of five working groups currently supporting the SCoG by acting on the Global Geodetic Reference Frame Roadmap Implementation Plan. As a component of the UN GGIM Subcommittee on Geodesy, the ETCB Working Group 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 and/or Sendai Framework for Disaster Risk Reduction are identified.

The ETCB has developed a five-year strategy (see Appendix 1) with the vision:

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

and mission

The UNCCIM Working Group on Geodesy sub-committee on capacity building will coordinate and facilitate capacity building with a particular focus on regional needs and Member States with less capacity.

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 questionnaire, the ECTB wanted to summarise how the audience 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 would 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 State providing geodetic infrastructure to support the development of the GGRF might need capability in

VLBI and SLR etc. This led to the initial 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 would 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.

Given the global nature of the target audience, it was agreed that an online questionnaire would be the most effective means of gathering feedback from a geographically diverse target audience. The Questionnaire was hosted on Google Sheets[1] in February 2018, and at time of writing (October 2019) was still open for feedback after twenty-two months. For the purposes of this paper, all those responses recorded at the end of October 2019 were included in this evaluation. Feedback from each section of the questionnaire has been gathered, analysed and presented in summary form with noteworthy findings and observations, along with a set of initial proposals.

It must be mentioned that 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 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 policy makers.

Given this development intention around the GGCE, it was clear that feedback gathered by the ETCB 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.

[1] UN-GGIM SCoG ETCB Questionnaire – Reference Frame Competency 2018/19 https://docs.google.com/forms/d/128LHyUCYsXRn9hQSdtGGa54XniAVPRjeRws3e0Dva9o/viewform?ts=5d9e42bf&edit_requested=true

2. RESULTS – THE RESPONDENTS

This section provides information about the Respondents and their affiliation. It was hoped to receive feedback from each Member State's UN-GGIM Head of Delegation, national agency representatives, decision-makers, and geodetic community leaders in each State.

A total of ninety-eight responses were received from a total of sixty-five Member States in the twenty-two months since the first posting of the survey. The following figures show the country location of each respondent, and the breakdown of the respondents in terms of their organisation type, affiliation and role.

Figure 1 – Locations of the ninety-eight Respondents from sixty-five Member States to the ETCB RF Competency Survey 2018/19

AFFILIATION	COUNT
No official affiliation / Other	42
Member of UN-GGIM Member State delegation	30
No Response	10
Head of UN-GGIM Member State delegation	10
Member of UN-GGIM Intergovernmental organization delegation	4
Member of UN-GGIM Non-governmental organization delegation	1
Member of UN-GGIM UN System and related organizations delegation	1
Total	**98**

Table 1 – Breakdown of Respondents by Affiliation

In terms of Affiliation, at least 46% were from UN-GGIM delegations. Government agencies made up approximately 71% of identified respondents, with 225 from academic organisations and just 3% from the private sector.

ORGANISATION / AGENCY	COUNT
Governmental (National Mapping Agency/Cadastre)	56
Academic (University or Research Institution)	21
Governmental (General)	5
Government (Other)*	5
Governmental (Military)	2
Governmental (Other Scientific Administration or Agency)	2
Non-governmental Organization	2
Academic (Vocational Training)	1
Governmental (Geospatial Intelligence)	1
Private Sector (Engineering Services or Consulting)	1
Private Sector (Mapping or Geospatial Information)	1
Private Sector (Other)*	1
Total	**98**

Table 2 – Breakdown of Respondents by Organisation / Agency Type

Respondents held a wide range of positions with a total of seventy-eight 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 on the relevant competencies. Those countries were: Argentina, Australia, Belgium, Brazil, Burkina Faso, France, India, Italy, Mali, Marshall Islands, Philippines, Samoa, Senegal, Uganda and Uruguay.

3. RESULTS – LEVELS OF REFERENCE FRAME COMPETENCY

This section covers the results for the Responders' 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 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 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: • GNSS • Reference frames, including geoid models, vertical and horizontal datums • Geospatial information integration and interoperability	• Educational institutions – universities and polytechnics • Government geodetic, survey and mapping agency • Private companies • Global Geodetic Centre of Excellence (GGCE) member	Countries that might have one CORS and maintain a traditional geodetic network of reference marks.
2	The above plus knowledge of: • Constructing, building and running a small CORS network • GNSS processing using commercial / consumer off-the-shelf software • Least squares processing and provision of datum access • Geoid models, determinations, precision, and basic implementation • Implementation of a vertical datum including use of geoid models	• Educational institutions – universities and polytechnics • UN-GGIM Geodesy Capacity Group • FIG / IAG • Government geodetic, survey and mapping agency • Private companies • GGCE member	Countries with small CORS network and those who adopt global reference frames for their nation reference frames.
3	The above plus high knowledge of: • Implementing and running large CORS networks • High-end GNSS processing and datum access • Geoid model computation and implementation into a vertical datums • Monitoring earth dynamics and including in datum realization • Geodetic database management	• Specialized courses – e.g. geoid school • UN-GGIM Geodesy Capacity Group • IAG / FIG • Government geodetic, survey and mapping agency • Private companies • GGCE member	Countries with a more extensive CORS and developing their own specialized national and vertical datum.
4	The above plus expert knowledge of: • Reference frame determination and computation • High-end GNSS analysis and processing • SLR including analysis and processing • VLBI including analysis and processing • Gravity collection, processing and geoid determination • Analysis centre – combining various geodetic techniques to determine reference frame parameters • Use of other potential geodetic techniques – e.g. DORIS and InSAR	• IAG • Specialist training courses run by space agencies, national mapping agencies, and others – e.g. on VLBI or SLR • Private companies • GGCE member • Specialized software training courses – e.g. Bernese and GipsyX	Countries engaged in Global Reference Frame determination and Geodesy Science.

Table 3 – Matrix of Predefined Levels of Reference Frame Competency requirements (ETCB (2018))

Respondents were provided with this table for reference and invited to evaluate the sovereign capabilities of their national GSO in terms of defining, maintaining and operating their

national geodetic reference frame with respect to these levels. In some cases, the respondents were self-evaluating, i.e. they were from the national mapping/geodetic agency.

As mentioned earlier, it is worth stating that respondents have different perceptions not only of the current RF competency level for their GSO, but also their target level – both of which are highly dependent on the size, location, topography and tectonic setting of their Member State (cf. the geodetic requirements of a landlocked nation on a stable plate might be quite different from a mountainous nation spanning two tectonic plates).

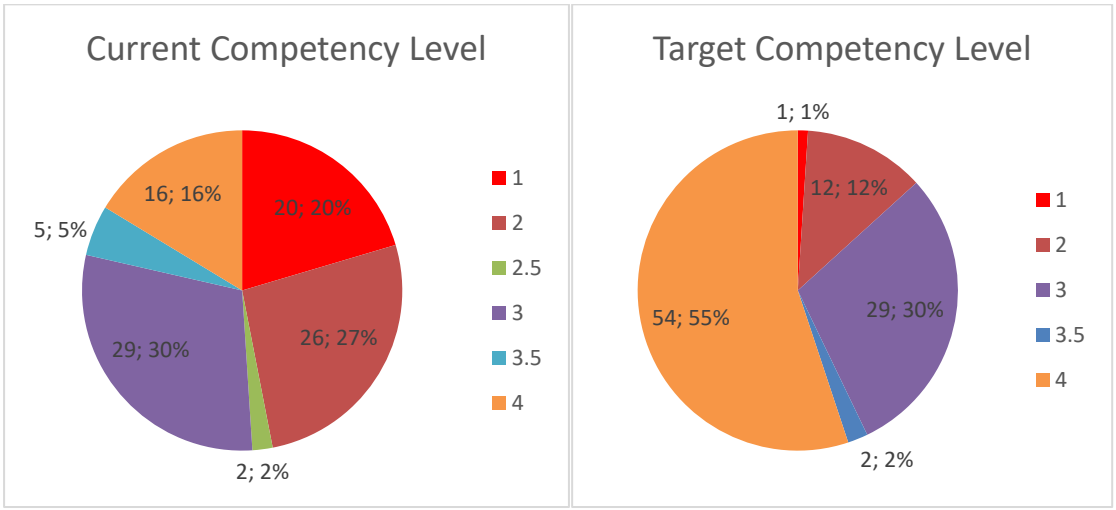

Figure 2 – Pie charts showing the Respondents' feedback on Current Competency Level (left) and Target Competency Level (right)

Deriving simple statistics on the variances of these parameters, the mean Current Competency Level is 2.5, and the mean Target Level is 3.4, clearly suggesting that organisations want to "level up".

Given the significant number of responses and feedback from developed and developing nations, there was a considerable spread of 'status quo' responses. In total, respondents felt that sixteen Member States had already reached the appropriate level of Reference Frame competency and required no additional specific training (other than ongoing retraining and keeping up to date with emerging techniques and technologies). These countries included: Australia, Argentina, Belgium, Brazil, Chile, Germany, Finland, France, Hong Kong, Honduras, India, Italy, Japan, Mali, Netherlands, New Zealand, Norway, Slovenia, Slovakia, Sweden, UK and USA. It is noted for several of these cumulative national responses, that there were some variances in assessments of current and future desired competency. For example, one State provided feedback from three different respondents – two felt that a Level 4 competency had already been attained, whereas the third respondent felt that Level 2 was a fair estimate of both the current and target competency levels for State. Similar levels of variability were seen across most nations for which there were multiple respondents.

One common takeaway from the majority of all ninety-eight respondents, was that regardless of whether a higher level of competency was aspired to or not, they would all have challenges in maintaining their current and target competencies in all relevant technologies and techniques as their organisations evolved, taking into account the typical turnover of staff, budgeting cycles and in several cases, political priorities. This will be covered more in the next section.

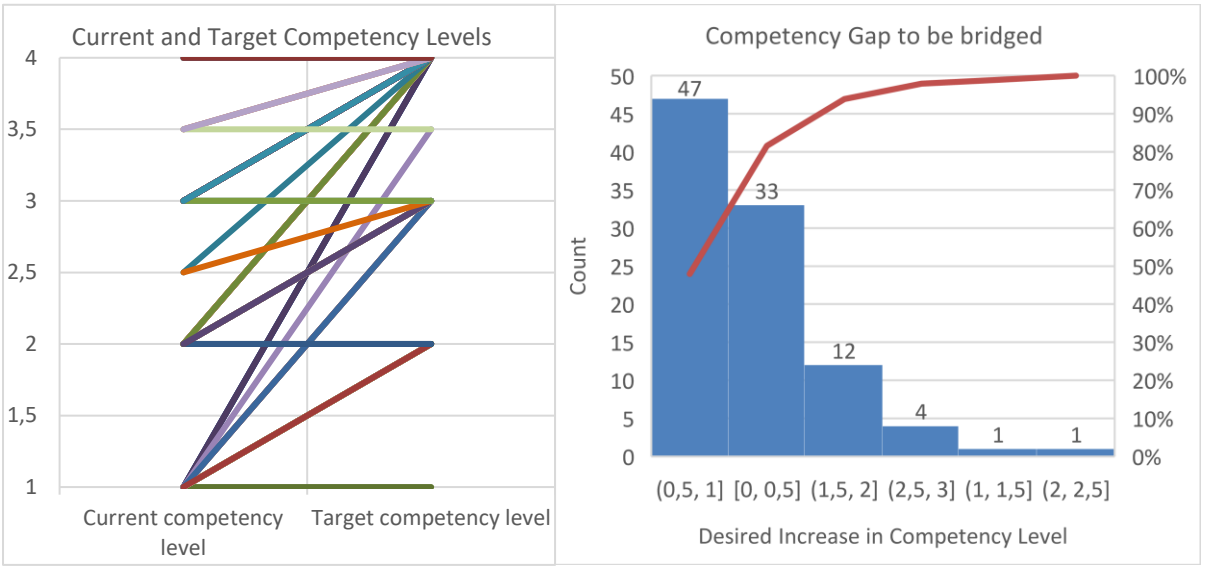

Figure 3 – Breakdown of Current and Future Competency Levels (left) and Histogram quantifying the Gap in Competency Levels to be bridged

The feedback on Competency level evaluations highlights the respondents' subjective needs on how to raise their levels of RF competency to their target level. An additional request for the expected duration needed for this improvement was made to bridge the gap between current and target competency levels, and the results grouped into bins of four years.

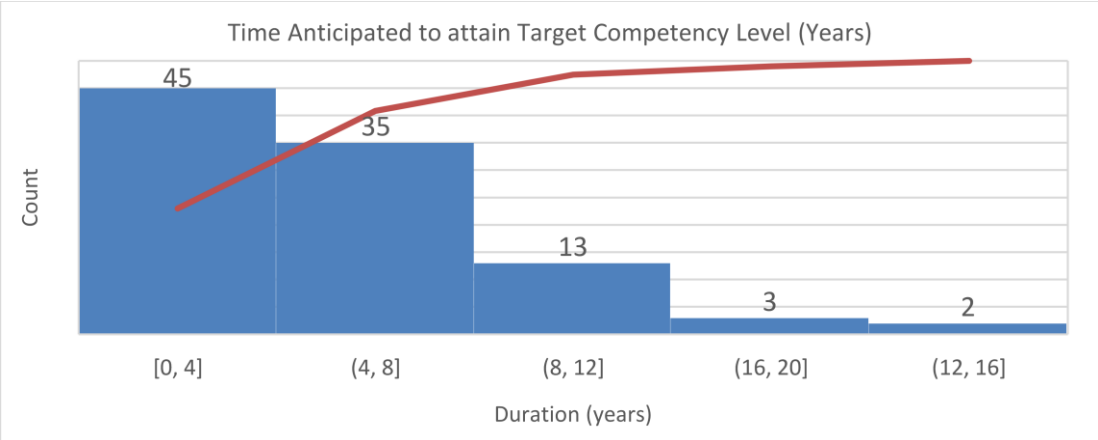

Figure 4 – Time Anticipated to attain Target Competency Level (Years)

One noteworthy observation on the anticipated duration of these improvements is that the greatest improvement can be achieved within the timeframe of four years, assuming resources and plans are delivered successfully and on time. This should be duly noted for future ETCB activities, by developing short well-defined agendas allowing organisations to complete them swiftly whilst maintaining progress and feeling a sense of achievement.

4. RESULTS – TRAINING NEEDS

The next section of the survey went into more detail about what the respondents felt was required to be able to raise their competencies. Based on the cumulative experience of the ETCB members who drafted the survey, a choice of predefined requirements were offered to respondents in the questions. The following four tables provide summaries of the questions, their predefined selections and options, along with the results.

Which Level 1 competency requirements are needed to achieve your future competency level?	COUNT
N/A or No Response	54
Basic understanding of Reference frames, including geoid models, vertical and horizontal datums	41
Basic understanding of GNSS	22
Other	7

Table 4 – Feedback on Level 1 Competency Requirements

It is noteworthy that while twenty respondents ranked themselves as being currently at Level 1, there were a larger number of responses for training on basic understandings of GNSS and Reference Frames. It is felt that this reflects the ongoing challenges to maintaining core technical levels in existing and new departments given staff turnover and personnel resourcing issues.

Which Level 2 areas of competency are needed to achieve your future competency level? (Knowledge building on Level 1)	COUNT
N/A or No Response	44
Least squares processing and provision of datum access	34
Implementation of a vertical datum including use of geoid models	31
Constructing, building and running a small CORS network	29
GNSS processing using standard software – e.g. Trimble, ComNav (Compass Solution), Leica (LGO)	25
Other	3

Table 5 – Feedback on Level 2 Competency Requirements

The general trends for required Level 2 competencies:

- A greater number of requests though for training around geoid models and vertical datums – should be considered in the Proposals section and by existing regional Capability Development Networks (CDN) to arrange for additional workshops.
- Training on GNSS CORS networks and associated GNSS processing software is a constant request.

Which Level 3 areas of competency are needed to achieve your future competency level?	COUNT
Geodetic database management	54
Monitoring earth dynamics and including in datum realization	49
Geoid model computation and implementation into a vertical datum(s)	48
High-end GNSS processing and datum access	46
Implementing and running large CORS networks	39
N/A or No Response	31
Other	4

Table 6 – Feedback on Level 3 Competency Requirements

The general trends for required Level 3 competencies:

- More than half of respondents felt that the management of geodetic databases is a necessary requirement and should be considered in future workshops. There may be the possibility to get the private sector involved with this.
- Training on GNSS CORS networks and associated GNSS processing software is a constant request.
- A greater number of requests for training around geoid models and vertical datums – should be considered in the Proposals section and by existing regional CDNs to arrange for additional Workshops.

Which Level 4 areas of competency are needed to achieve your future competency level? (Knowledge building on Levels 1, 2, and 3)	COUNT
High-end GNSS analysis and processing	57
Analysis centre – combining various geodetic techniques to determine reference frame parameters	56
Reference frame determination and computation	52
Gravity collection, processing and geoid determination	52
Use of other potential geodetic techniques – e.g. DORIS and InSAR	50
SLR including analysis and processing	48
VLBI including analysis and processing	44
N/A or No Response	13
Other	4

Table 7 – Feedback on Level 4 Competency Requirements

The general trends for required Level 4 competencies:

- Training on advanced GNSS analysis and processing is a constant request, presumably as GNSS constellations evolve with additional signals and new receiver technologies.
- Awareness about Analysis centres and their products is of significant interest.
- A greater number of requests though for training around geoid models and vertical datums – should be considered in the Proposals section and by existing regional CDN to arrange for additional Workshops.

5. FINDINGS

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.

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

- **Timing** – the window for responding to this survey was almost two years, so the status quo in some GSOs may have changed during this time – hopefully for the better.
- **Missing Responses** – in the situation where responses were not provided 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 Grading Subjectivity** – these are self-proclaimed competency evaluations, open to the subjectivity of each respondent, their overall knowledge, awareness and experiences, which 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 one-hundred and ninety-five Member States, all with the need of GRF, however this questionnaire was only answered by sixty-five Member States. Greater participation in this (or a follow-on) survey may occur as and when the future GGCE is announced.

CHALLENGES

A considerable number of noteworthy observations have been summarised hereafter which provide a succinct insight of the global challenges faced by respondents and their respective agencies. Further details were afforded to the survey, however the essence of the most common challenges have been distilled in the following sections.

Institutional challenges (typical but no limited to GSOs and federal organisations)

- Lack of ability (experience / knowledge) and support within the organisation to justify the establishment and on-going maintenance of geodetic infrastructure and systems
- No specific and credible mechanisms and frameworks to enable the sharing of technical knowledge and to support training on the various aspects of the geodetic data /information cycle
- Lack of categorization of existing technical knowledge and other resources that may enable intuitive and interoperable use
- The desire to immediately establish a reference frame rather than learn how to do it; dur to a lack of resources and capability leading to outsourcing as the preferred option
- Unaware how to and whom to contact in various UN and international organisations
- Lack of understanding of the strategy, approach, and requirements to accessing (or even becoming) a regional data repository or analysis centre

Capacity Building / Training and Education challenges

- The most appropriate person(s) from agency are not always selected / invited to attend relevant training / workshops etc
- There is often no follow-up or implementation support for those staff who have attended the appropriate training / capacity development programs
- There are many "experts or specialists" available to provide training on core competencies but no system to access or support the "trainers / educators"
- Many CDN are staffed by international experts volunteering their assistance beyond their current role, and thus their ongoing availability is due to the good will of their employer which can be limited/restricted or unreliable

Barriers to increasing Competencies

- Lack of resources including:
    - budget (fiscal and personnel allocation)
    - equipment, software, geodetic and supporting infrastructure (i.e. power, communications)
    - socio-political support
- Lack of people with sufficient knowledge, qualifications and skills, and little consideration of succession planning
- Lack of access to specialists or experts or supervisors in geodetic surveying
- Lack of training and educational institutes and facilities
- Lack of policies and legislative basis, effecting lack of support from politicians and decision makers
- Challenges due to multiple open data standards and the unreliable interoperability of geodetic data globally especially when GSOs' core competencies are so different

- Lack of appropriate material to advocate the importance, achievements and support the justification of modernised GRSI (i.e. return on investment analysis and statistics, case studies) to suit the target audience

SOLUTIONS

The following section comprises of direct feedback submitted to the survey and possible solutions as derived by the authors during analysis.

What training will help the RF competency needs of agencies?

- Improved tertiary education on the fundamentals of surveying i.e. competencies prior to Level 1
- Increased Level 1 and Level 2 training on geodetic theory and implementation:
    - Determination and computation of Reference Frame parameters; Height unification and modernisation; Geoid determination; Network adjustments; Transformation parameters derivation
- Geodetic data management fundamentals and planning
- Clear statement of the requirements to becoming a regional data repository or analysis centre; and understanding the operations, services and products
- 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

Resources and Resourcing solutions

- More resourcing, investment, training, scholarships, grants etc. from internal and external sources – preferably facilitated from a "centralised" group
- Awareness of funding options and mechanisms – what are they, how to access, understanding the eligibility criteria and requirements, and the process to apply
- Succession planning for personnel resources in addition to regular participation in regional CDN events and workshops

Training and Education solutions

- Increased frequency of regional training to attain a consistent approach and community spirit
- Consider information exchange seminars on new technologies, applications and systems that affect GNSS, geodesy and positioning
- Greater recognition and advocacy of geodesy and its benefits to stakeholders and community

- Courses during the non-academic periods i.e. “summer schools”, workshops (such as UNOOSA, IAG etc.)
- Make available, easily discoverable, intuitively usable, and interchangeable training and reference materials, via online platforms
- Sustainable ways to bridge the knowledge gap and digital divide, especially in developing countries and/or countries in transition
- Strategies to encourage more support / effort / assistance from those geodetic organisations at Level 3 and 4
- Better coordination by the agencies who have possess the required “levels” and global / regional bodies and global organisations (i.e. FIG, IAG, UNOOSA et al.)

Sharing and Collaboration solutions

- Share and exchange both resources and data across borders where possible
- More capacity development to improve sharing of geodetic data – specifically workshops on the advocating the benefits of sharing, and development of relevant policy to support implementation
- Develop pathways, structures, frameworks and roadmaps which facilitates 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

Increased Regional Involvements

There are several examples where ongoing regional initiatives have demonstrated moderate success. One such example is how the FIG Asia Pacific Capability Development Network (FIG AP CDN) and its enduring collaboration with the ETCB in Asia and the Pacific region. Participants from these groups have run and contributed to a significant number of successful reference frame in practice workshops since 2013, helping to:

- Provide advice on the importance of strategic and operational planning to develop geodetic and geospatial communities, in this instance across Pacific Island Country Territories (PICTs).
- Advocated the role and value of geodetic and geospatial information to resolving and managing the impacts of climate change / sea level rise, and natural disasters such as cyclones, earthquakes and tsunamis.

A significant /common theme for workshops run by AP CDN is into the education, planning and maintenance of GNSS CORS infrastructure capability and geodetic datum modernisation activities. International Federation of Surveyors (FIG) Commission 5 has a well-known and industry recognised workshop entitled ‘Reference Frames in Practice (RFIP)’ that has been run numerous times alongside conferences, workshops and other geospatial events, not only

those organised by FIG. Further information on the FIG AP CDN and its involvement can be found at https://www.fig.net/news/news_2019/11_ap_cdn.asp

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.

6. SUMMARY AND RECOMMENDATIONS

Based on the collective analysis and weighting of survey responses, there are four significant points that 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 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 who 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 benefit 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.

RECOMMENDATIONS

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	GGCE could become the central point for ***organising and facilitating*** the	

	a centralised Facilitator	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 8 – Recommendations for ongoing ETCB activities on raising the level of Global Reference Frames Competency

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 building*** Findable, Accessible, Interoperable and Reusable (FAIR) so it can be shared globally and used to improve decision making.

Ultimately, the successful establishment of the GGCE as proposed by the UN-GGIM SCoG would be best positioned to deliver, implement and facilitate an enhanced, fit-for-purpose and globally sustainable capacity building initiative for ongoing GGRF education and training.

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BIOGRAPHICAL NOTES

Dr. Ryan KEENAN, since completing his PhD in GPS, Geodesy & Navigation (University College London), Ryan has over twenty years of GNSS positioning industry experience initially with specific focus on high-precision applications for the survey, geodesy, machine control, agriculture and mining sectors. More recently, in his role as Principal Consultant at Positioning Insights, Ryan has been providing independent advice on location technologies to governments and numerous SMEs across the Asia Pacific and Oceania regions. Dr. Keenan is currently co-Chair of FIG Commission 5's Working Group 4 on 'GNSS', a member of the FIG Asia Pacific Capacity Development Network and member of two UN GGIM Subcommittee on Geodesy Working Groups – Education, Training and Capacity Building, and Outreach & Communication.

Allison CRADDOCK is a member of the Geodynamics and Space Geodesy Group in the Tracking Systems and Applications Section at the NASA Jet Propulsion Laboratory in Pasadena, California, USA. She is the director of the International GNSS Service (IGS) Central Bureau, manager of external relations for the International Association of Geodesy's Global Geodetic Observing System and staff member of the NASA Space Geodesy Program.

Mikael LILJE, Manager of International Department at Lantmäteriet (the Swedish mapping, cadastral and land registration authority). Mikael has been working at Lantmäteriet since 1994 mainly at the Geodetic Infrastructure Department where he was the manager between 2009 and 2019. In his current position he is responsible for the international services that Lantmäteriet is involved in, mainly in Africa and Eastern Europe. He is also supporting Lantmäteriet's management team with international cooperation on UN, Global, European and Nordic level. Mikael is currently leading the Working Group on Education, Training and Capacity Building within the UN GGIM Sub Committee on Geodesy. Mr. Lilje has been an active member of the FIG since 1998 and is now FIG vice President.

Rob SARIB, Director Survey / Surveyor-General, in the Land Information Group of the Northern Territory Government of Australia's Department of Infrastructure Planning and Logistics. Rob Sarib obtained degree in Bachelor Applied Science – Survey and Mapping from Curtin University of Technology Western Australia in 1989. He also holds a Graduate Certificate in Public Sector Management received from the Flinders University of South Australia. Rob was registered to practice as a Licensed Surveyor in the Northern Territory, Australia in 1991. Since then he has worked as a cadastral and geodetic surveyor, and a land survey administrator. Mr. Sarib has been an active member of the FIG since 2002, and is now Chair of the FIG Asia Pacific Capacity Development Network. He is presently a Board member of Surveying and Spatial Sciences Institute; the Chair of the Surveyors Board of

Northern Territory; and member of the Inter-governmental Committee on Survey and Mapping – Australia.

Graeme BLICK obtained his Bachelor of Surveying from Otago University in 1980. He worked for GNS Science before spending time at the University NAVSTAR Consortium in Boulder Colorado utilising GPS to monitor crustal movements on several international projects. In 1995 he moved to Land Information New Zealand (LINZ), New Zealand's National Survey and Mapping agency. He is the Chief Geodesist and Group Manager of the Positioning and Resilience Group where he continues to work on and manage the development and implementation of the geodetic system in New Zealand and develop a new resilience programme of work for LINZ.

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APPENDIX 1

UN-GGIM GGRF ETCB 5 Year Strategy

Vision

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

Mission

The UNCCIM Working Group on Geodesy sub-committee on capacity building will coordinate and facilitate capacity building with particular focus on regional needs and 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 sub-committee on Geodesy*
- *Work with regional groups to determine training needs at regional levels*

Using GGRF-wide 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.*

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*

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*

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 Sub-committee on Geodesy*
- *Work with the GGRF WG Outreach and Communications Focus Group to ensure optimal development and delivery of educational and advocacy materials*

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

- *Establish minimum training needs for a set of standardized tasks, spanning infrastructure, academic, and long-term sustainability.*
- *Established training resources and centres of expertise*

Encourage stakeholder and member 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

- *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.