**The Roadmap**

**Guidance on how to build a country’s Geospatial Reference System**

Version 0.1

7 April 2025

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**About the UN-GGCE**

At its tenth session in August 2020, the United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM), in making decision 10/104, welcomed and supported an offer by Germany to establish and host what has now become the United Nations Global Geodetic Centre of Excellence (UN-GGCE) at the UN Campus in Bonn, Germany. The UN-GGCE, established in March 2023, is envisioned to be a federated centre and welcomes offers of support from Member States, including financial contributions, in person secondments, and virtual secondment.

For more information about the UN-GGCE please visit: <https://ggim.un.org/UNGGCE/>

**Document in development**

This is a preliminary version of The Roadmap based on the information available to the UN-GGCE as of April 7, 2025. Further information will be gathered throughout 2025 as the UN-GGCE implements capacity development training sessions. Updates to The Roadmap will be made available throughout 2025 and a final version will be made available in all UN languages in early 2026.

**Feedback and comments**

Your feedback and comments on this report are welcome.

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Introduction

Purpose of this document

The United Nations Global Geodetic Centre of Excellence (UN-GGCE) vision is a future where all countries have strong political support for geodesy which enables them to – together – implement the General Assembly Resolution 69/266[[1]](#footnote-2) and accelerate the achievements of the Sustainable Development Goals to derive social, environmental and economic benefits. Key to a country achieving their goals is an accurate and reliable Geospatial Reference System which enables them to align and combine geospatial information and make better decisions.

The Roadmap provides a guidance on how to modernise and implement a country’s GRS to ensure that all geospatial data—whether from maps, satellite imagery, or GNSS-enabled technologies—is accurately aligned to a unified, nationally consistent way. This foundation supports precise positioning, underpins smart infrastructure, enhances resilience to climate change and natural disasters, and facilitates integration with international geodetic frameworks. The Roadmap also defines governance structures, guides institutional responsibilities, and prioritizes investments in infrastructure and capacity development.

What is a Geospatial Reference System?

The Geospatial Reference System of a country includes a number of elements (Figure 1) including:

* Datums or reference frames
  + Geometric datums (e.g. geocentric datums)
  + Physical datums (e.g. height datums)
* Transformation and Conversion Methods to transform from one datum to another
* Standards to ensure positioning information is Findable, Accessible, Interoperable and Reusable (e.g., EPSG, ISO)
* Infrastructure, including a national network of Global Navigation Satellite System Continuously Operating Reference Stations (GNSS CORS) and survey marks
* A modern GRS has a geometric datum aligned to a recent realization of the International Terrestrial Reference Frame (ITRF) and a physical datum which has a well-defined connection to the International Height Reference Frame (IHRF)
* The GRS of a country can be applied to:
  + define latitude, longitude, height, orientation and gravity;
  + model dynamic, geophysical processes that affect geospatial measurements;
  + transform and convert data;
  + ensure positioning information is Findable, Accessible, Interoperable and Reusable, and;
  + provide an authoritative and accurate ground station network to support positioning applications.

Without a national GRS, which is closely aligned to ITRF, geospatial data is inconsistent and unreliable, limiting the ability of Member States to understand and address complex challenges.

The accuracy of a country’s GRS impacts on its capability and capacity to collect and manage nationally integrated geospatial information and make evidence-based decisions and policies. In addition to the traditional survey, mapping and navigation fields, an accurate GRS is essential for Earth sciences, economic development and sustainability, public safety and disaster management, land and water administration, and environmental management.

A diagram of a country

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Figure 1: Example of a country Geospatial Reference System.

*Guidance:*

* *At the top of this diagram is an icon with a pause symbol in the middle which represents the new* ***static datum*** *for a country. A static datum is a datum in which the coordinates of features do not change over time. They are held fixed at a specific epoch, for example, 1 Jan 2027. A static datum is useful for many applications where you do not want coordinates to change over time. For example, the property boundary coordinates of a house. Most modern static datums are aligned to recent realizations of the International Terrestrial Reference Frame – the ITRF – because the reference frame of GNSS constellations is aligned to the latest realisation of ITRF (at this time it is ITRF2020).*
* To switch between the new static datum and the old static datum, as shown at the bottom of the diagram, you have to use **transformation parameters** as indicated by the blue icon in the middle of the diagram. The static datum provides a foundation on which we can combine and align spatial datasets like satellite imagery, topography, natural hazards and building locations. This alignment greatly improves our understanding of the data which is pivotalto improving our decision-making capability.
* The next component is a **time dependent reference frame**. A time dependent reference frame is one where your coordinates of features like roads, waterways, property boundaries change over time with the movement of the tectonic plates. An example of a time dependent reference frame is the ITRF2020. Another example is the World Geodetic System 1984. To transform between a static datum and a time dependent reference frame, we can again use transformation parameters. In this case, there are 14 parameters because we have velocities associated with each of the 7 transformation parameters. A country Geospatial Reference System may or may not include a national time dependent reference frame. A time dependent reference frame is especially useful for intelligent transport systems like autonomous vehicles and for location-based services to ensure users are able to access geospatial datasets in real-time in the same reference frame as the GNSS positioning information they are receiving.
* The next important inclusion for a modern geospatial reference system are the physical geodesy components. This includes **geoid models** used to transfer geometric heights to physical heights, and vice versa) and **height datums** as shown on the right-hand side of this diagram. The height datums are a physical datum which defines the zero point for elevation or depth measurements. An example is Mean Sea Level.

2. Understand the current Geospatial Reference System and needs of stakeholders

Understanding the current Geospatial Reference System and stakeholder needs is essential before making any changes, as updates can be costly, time-consuming, and disruptive if not clearly required. Changes that are unnecessary may waste resources and impact systems that already meet user needs. Also, consider that any updated components must not only be justified by stakeholder demand but also meet the accuracy requirements of users both now and into the future.

**Action 1.1:** Document the current Geospatial Reference System in the form of a Geodesy Factsheet for your country (Appendix A).

**Action 1.2:** Create a diagram describing your country’s GRS (Figure 1).

*Guidance:*

* *Use this to understand the elements of the GRS you currently have and how they fit together. You can then present this to stakeholders to explain the current situation on one page.*

**Action 1.3:** Identify and understand the needs of stakeholders.

*Guidance:*

* *Consult with stakeholders to determine what their accuracy requirements are for the GRS now and in the future. Furthermore, understand what legal and policy changes would be required if the GRS was updated. Stakeholders include:* 
  + *Government agencies including national mapping agencies, land registries, defence, meteorology, policy, aviation, maritime and space agencies.*
  + *Private Sector: Companies that rely on geospatial data for their operations, such as surveying firms, engineering companies, underground infrastructure operators, telecommunications, water, power and technology providers.*
  + *Academia and Research Institutions: Universities and research organizations that specialize in geospatial sciences and can provide expert insights and research support.*
  + *Non-Governmental Organizations (NGOs): Organizations that use geospatial data for various purposes, including environmental monitoring, disaster response, and community development.*
  + *Professional Associations: Groups representing professionals in the geospatial field, such as surveyors, cartographers, and GIS specialists.*
  + *Public and Community Groups: Engaging with the general public and community organizations to understand their needs and concerns regarding geospatial data.*
  + *International Organizations: Bodies that set global standards and practices for geospatial data, ensuring compatibility and cooperation on an international level.*

**Action 1.4:** Summarize the needs of stakeholders and decide which elements of the GRS need updating.

*Guidance:*

* *Based on the needs of stakeholders, decide which components of the GRS need updating to meet current and future requirements.*
* *Based on this information, choose which of the remaining steps you need to do.*

**Action 1.5:** Classify stakeholders using a matrix of their level of interest and level of influence (Figure 2).

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Figure 2: A template to identify and classify stakeholders.

*Guidance:*

* Assess the level of impact and level of influence of stakeholders and consider the approach you will use to consult or communicate with them.
* When consulting or communication with stakeholders, emphasise what is in it for them, and identify potential blockers in the relationship.
* Invest a sufficient amount of time in this step because stakeholders will determine the level of support and resources you have to carry out your proposed activities.

1. Communicate why an update to the Geospatial Reference System is needed

To make geodesy understandable and visible to policymakers, students, the general public, and even professionals in fields that rely on geospatial, it's essential to simplify its concepts, use relatable examples, and emphasize its real-world applications. Ultimately, promoting geodesy’s contributions to the economy, environment and society ensures that it is recognized for its vital role in solving global challenges.

**Action 2.1:** Create and implement acommunications plan (Appendix B).

*Guidance:*

* To make geodesy understandable and visible to policymakers, students, the general public, and even professionals in fields that rely on geospatial, it's essential to simplify its concepts, use relatable examples, and emphasize its real-world applications. Ultimately, promoting geodesy’s contributions to the economy, environment and society ensures that it is recognized for its vital role in solving global challenges.
* Review Communications presentation from UN-GGCE Capacity Development Workshop <https://ggim.un.org/UNGGCE/documents/4_1_1%20-%20Communications.pptx>
* Review Communications material from Australia (<https://www.icsm.gov.au/datum/gda2020-fact-sheets>) and New Zealand (<https://www.linz.govt.nz/sites/default/files/factsheet_modernising-height-data_20170913.pdf>

1. Establish good governance

Establishing good governance for the update to a geospatial reference system ensures clear decision-making, accountability, and coordination among stakeholders. It helps manage risks, resources, and timelines effectively, keeping the project on track and aligned with national or organizational priorities. Strong governance also promotes transparency and stakeholder confidence, which are essential for widespread adoption and long-term sustainability.

**Action 3.1:** Establish or strengthen a country level geodesy governance structure with a senior management Steering Committee and Working Groups.

*Guidance:*

* The national geodetic or geospatial authority or agency is often the lead agency responsible for overseeing the development, maintenance, and implementation of the national GRS. The lead national geodetic or geospatial authority or agency should collaborate and communicate with stakeholders identified in the stakeholder assessment (**Action 1.3**).
* A Steering Committee should be established or strengthened with senior level members from a range of key stakeholder groups. The Steering Committee provides strategic oversight, setting the direction and ensuring that the overall goals and objectives of a project or system are met.
* Working Groups report to the Steering Committee and focus on practical execution of projects, managing resources, timelines, and ensuring that tasks are carried out according to the plans of the Steering Committee.
* The UN-IGIF Appendix 1.1 (<https://ggim.un.org/UN-IGIF/documents/SP1%20-%20Appendices%2013Dec2019%20GLOBAL%20CONSULTATION.pdf>) provides a template for a Steering Committee Charter which includes the mission, roles and principles of a Steering Committee.
* Review the Governance presentation from UN-GGCE Capacity Development Workshop <https://ggim.un.org/UNGGCE/documents/4_3_1%20-%20Governance.pptx>

1. Develop business cases

A business case for updating the country geospatial reference system should justify the investment by clearly outlining the benefits, costs, and expected outcomes. It provides decision-makers with evidence to support funding and prioritization, aligning the project with broader strategic goals of the government.

**Action 4.1:** Develop a business case/s which provide a clear and concise argument that demonstrates why an investment in the GRS is worthwhile.

*Guidance:*

* The business cases should be written in a way policy makers can understand and should explain why change is needed, resources required, potential value or gains for the country and risks associated with the project.
* The UN-IGIF Appendix 3.8 (<https://ggim.un.org/UN-IGIF/documents/SP3-Appendices-19Jun2020-GLOBAL-CONSULTATION.pdf>) provides a draft structure (and example) of a business case which covers five key perspectives – the strategic case (why now?); economic case (quantify the financial benefits including cost efficiencies and public good benefits); commercial case(how the customers and potential partners will be engaged); financial case (funding sources); and management plan (what capabilities and resources are required for implementation to be successfully achieved?).
* Review the Business Case Development presentation from UN-GGCE Capacity Development Workshop <https://ggim.un.org/UNGGCE/documents/4_2_1%20-%20WHAT%20Developing%20business%20cases%20&%20Group%20Activity.pptx>
* Review the UN-IGIF Funding Guide presentation <https://ggim.un.org/meetings/2025/Jeddah/documents/3.2_Sustainable_funding_guide_launch.pdf>
* Review the Australian example of how a Business Case was developed and presented to government:
  + from the Third UN-GGCE international Advisory Committee meeting <https://ggim.un.org/UNGGCE/documents/20250310%20Business%20Case%20PNT%20in%20Government%20-%20Australia.pdf>
  + Positioning Australia industry case studies <https://www.ga.gov.au/scientific-topics/positioning-navigation/positioning-australia/case-studies>
  + Positioning Australia economic benefits study <https://frontiersi.com.au/wp-content/uploads/2018/08/SBAS-Economic-Benefits-Report.pdf>
* Review the EUSPA Market Report <https://www.euspa.europa.eu/sites/default/files/external/publications/euspa_market_report_2024.pdf>
* Review the Victoria (Australian) example of a Business Case was developed and presented to government for Airborne Gravity Data acquisition (Appendix C).

1. Create a project plan

Developing a project plan is essential to define the scope, timeline, resources, and responsibilities for updating a geospatial reference system. It provides a structured roadmap that guides the project team, helping to manage risks and stay on schedule. A clear plan also facilitates communication and coordination among stakeholders, ensuring that objectives are met efficiently and effectively.

**Action 5.1:** Develop a project plan for the elements of the GRS you will be updating which includes scope, timeline, resources, and budget required for the GRS development.

*Guidance:*

* The UN-IGIF Appendices 1.4 (<https://ggim.un.org/UN-IGIF/documents/SP1%20-%20Appendices%2013Dec2019%20GLOBAL%20CONSULTATION.pdf>) provides a template of a country level action plan, considering content like agencies involved, contact person, objectives, deliverables, timeframe, budget estimation and funding status in one document.
* The UN-IGIF Appendices 1.5 and 1.6 (<https://ggim.un.org/UN-IGIF/documents/SP1%20-%20Appendices%2013Dec2019%20GLOBAL%20CONSULTATION.pdf> )contain tools to monitor and evaluate the plan as well as setting success indicators to monitor progress.

1. Establish a GNSS network

A GNSS infrastructure network is fundamental for providing the high-accuracy positioning data needed to establish and maintain a modern geospatial reference system. It enables real-time access to consistent, accurate location information across the country, supporting sectors like transportation, agriculture, construction, and emergency response.

**Action 6.1:** Design a GNSS network

*Guidance:*

* Stations should be on stable ground with minimal subsidence or surface heave. At these sites, the objective is to provide a stable framework, not to observe movement of the land.
* Aim for relatively consistent spacing between GNSS sites and include sites on major islands and key locations.

**Action 6.2:** Install a GNSS network

*Guidance:*

* Consider using multi-GNSS capability (GPS, GLONASS, Galileo, BeiDou) to improve accuracy and resilience.
* Ensure consistent recording of GNSS data for future interoperability and reusability (i.e.., RINEX format, IGS standards).
* Standardize sampling rates (e.g., 1 Hz for real-time applications, 30s for long-term geodetic monitoring).
* Maintain metadata records (station location, hardware, software versions, environmental conditions).
* Consider using the information provided in the IGS Guidelines for Continuously Operating Reference Stations in the IGS: <https://files.igs.org/pub/resource/guidelines/Guidelines_for_Continuously_Operating_Reference_Stations_in_the_IGS_v1.0.pdf>
* Consider using the information provided in the ICSM Guideline for Installation and Documentation of Survey Control Marks: <https://www.icsm.gov.au/publications/guideline-installation-and-documentation-survey-control-marks-v22#:~:text=Guideline%20for%20Installation%20and%20Documentation%20of%20Survey%20Control%20Marks>

1. Collect GNSS data

**Action 7.1:** Collect and archive GNSS CORS data

*Guidance:*

* Establish a centralised data repository which could be a government-hosted data centre or cloud storage (AWS, Google Cloud etc). Ensure high-availability servers with backup power and disaster recovery.
* Have backups of the data in different locations.
* If possible, archive the data within your country and also share it with the regional scientific organisation who manages the regional reference frame (e.g. APREF, EUREF, SIRGAS).

**Action 7.2:** Collect and archive GNSS campaign data

*Guidance:*

* To propagate the datum from the GNSS CORS to survey ground marks where people can access it and use it. To do this, it is recommended that countries undertake a geodetic campaign to create a link between the GNSS CORS and survey control marks.
* This can be done by via GNSS campaigns; temporarily deploying GNSS equipment on survey marks around the country. By accurately measuring the location of those survey marks at the same time as collecting GNSS data from GNSS CORS, it is possible to create links (known as baselines) between the sites and compute accurate coordinates on the survey marks.

1. Process GNSS data

**Action 8.1:** Process GNSS CORS data

*Guidance:*

* The processing of GNSS CORS data on an ongoing basis is a complex process. Most countries are advised to share their GNSS CORS data with the regional scientific organisation who manages the regional reference frame (e.g. APREF, EUREF, SIRGAS) to have the data analysed for them.
* For a description on how this is done by Australia, review chapter 9 of the Australian Geospatial Reference System Compendium <https://www.icsm.gov.au/publications/australian-geospatial-reference-system-compendium>
* Review the information here <https://www.ga.gov.au/scientific-topics/positioning-navigation/positioning-australia/geodesy/asia-pacific-reference-frame>
* GNSS analysis
* AUSPOS – GPS site analysis <https://www.ga.gov.au/scientific-topics/positioning-navigation/geodesy/auspos>
  + OPUS – GNSS site analysis <https://geodesy.noaa.gov/OPUS/>

**Action 8.2: Process GNSS Campaign data**

*Guidance:*

* Consider the Report on the Analysis of the Asia Pacific Regional Geodetic Project (APRGP) GPS Campaign 2023 <https://un-ggim-ap.org/sites/default/files/media/docs/APRGP2023_AnalysisReport.pdf>

1. Perform national geodetic adjustment

Performing a national geodetic adjustment is crucial for the development of a unified, accurate, and consistent modern datum. It integrates data from various sources, including GNSS, levelling, and gravity observations, to minimize errors and discrepancies in the national geodetic network.

**Action 9.1:** Choose a ITRF realization and epoch to align to (e.g. ITRF2020@2024)

*Guidance:*

* Modern global navigation satellite systems (GNSS), including GPS, rely on the ITRF as a common reference frame. Aligning a national geodetic datum to the ITRF ensures accurate positioning and navigation.

**Action 9.2:** Choose the constraint for the national adjustment

*Guidance:*

* The constraint used for the adjustment is traditionally a set of “datum defining points” or “Fiducial Network” sites. For example, in Australia, there are 109 Australian Fiducial Network (AFN) sites, which define the Australian datum (<https://www.legislation.gov.au/F2017L01352/latest/downloads>). These sites are used as constraint in the national adjustment in Australia.
* If you contribute data to a regional reference frame, consider whether or not the analysis performed in the determination of the regional reference frame could be used.
* For a detailed description of this from an Australian perspective, review chapter 9 of the Australian Geospatial Reference System Compendium <https://www.icsm.gov.au/publications/australian-geospatial-reference-system-compendium>.

**Action 9.2:** Perform a national geodetic adjustment

*Guidance:*

* A national geodetic adjustment is used to update or refine the positions of geodetic control points using GNSS, levelling, and other geospatial data. This process corrects errors, accounts for land movement (such as tectonic shifts), and ensures that all control points are aligned within a unified geodetic reference frame, such as ITRF or a national datum. The adjustment enhances the precision and reliability of coordinates used for mapping, surveying, infrastructure development, and scientific applications.
* For access to open-source geodetic adjustment software, refer to DynAdjust, <https://github.com/icsm-au/DynAdjust>.
* Review the presentation on Aligning national geodetic datums to ITRF from UN-GGCE Capacity Development Workshop <https://ggim.un.org/UNGGCE/documents/1_2_3%20-%20Aligning%20national%20geodetic%20datums%20to%20ITRF.pptx>.
* Review the presentation What is a geodetic adjustment from UN-GGCE Capacity Development Workshop <https://ggim.un.org/UNGGCE/documents/2_1_2%20-%20What%20is%20a%20geodetic%20adjustment.pptx>.
* Review the presentation How to undertake a national geodetic adjustment from UN-GGCE Capacity Development Workshop <https://ggim.un.org/UNGGCE/documents/2_2_1%20-%20How%20to%20undertake%20a%20national%20geodetic%20adjustment.pptx>.
* Least Squares training presentations
  + Full presentation – <https://www.youtube.com/watch?v=T5YB_1Jpjp0> (1hr 42 mins)
  + Chapter 1 – What is Least Squares and why are we using it in DCM? <https://youtu.be/0YkjHsVgGMk> (26 mins)
  + Chapter 2 – Why do we iterate? <https://youtu.be/_iFg3Ho_cRI> (18 mins)
  + Chapter 3 – Weighting Observations <https://youtu.be/2yQCWblrQGs> (10 mins)
  + Chapter 4 – Constraints <https://youtu.be/WcwKv-vWUtk> (7 mins)
  + DynAdjust Q&A <https://youtu.be/WZN38NrPBeY>

**Action 9.3:** Document the procedure and include the new datum in international standards.

*Guidance:*

* Create a publicly available document which describes the process used to compute the national adjustment. For example, see the journal article published on the development of the most recent Australian datum <https://www.tandfonline.com/doi/full/10.1080/14498596.2023.2184429>.
* Include the new geodetic datum in EPSG, ISO Geodetic Register and national geodetic agency standards.
* Include metadata on datum sources, accuracy, and methodology.
* Ensure enough information is available so that the results are reproducible and publicly accessible if needed.

1. Develop 7-parameter transformation

The 7-parameter transformation is used to transform coordinates from the old geodetic datum to the new geodetic datum.

*Guidance:*

* Review the presentation Creating Transformation Parameters from UN-GGCE Capacity Development Workshop <https://ggim.un.org/UNGGCE/documents/3_1_2%20-%20Example%20-%20Creating%20transformation%20parameters.pptx>.
* This procedure only covers the Helmert (7-parameter) transformation – for rigid-body shifts. For distortion / deformation models, please see Step 11.

**Action 10.1:** Based on the needs of stakeholders, define the required accuracy for the transformation.

*Guidance:*

* Consider the information captured in the stakeholder engagement process.

**Action 10.2:** Gather coordinate datasets in both old geodetic datum and new geodetic datum.

*Guidance:*

* Use the highest accuracy geodetic control points. The positional uncertainty of the coordinates used in the computation of the transformation parameters will influence the accuracy of the transformation parameters.
* Ensure the distribution of geodetic control points in which you have coordinates in the old datum and the new datum is distributed relatively evenly across the area of interest.

**Action 10.3:** Compute transformation parameters

*Guidance:*

* This is traditionally done using the mathematical process of least squares to calculate translation (3), rotation (3), and scale (1) parameters. Review the presentation Creating Transformation Parameters from UN-GGCE Capacity Development Workshop <https://ggim.un.org/UNGGCE/documents/3_1_2%20-%20Example%20-%20Creating%20transformation%20parameters.pptx>.
* Validate the transformation by checking residuals and errors following the least squares computation process. If necessary, refine with additional data points.

**Action 10.4:** Validate the results and check if the accuracy of the transformation parameters meets the requirements of stakeholders.

*Guidance:*

* Apply the transformation parameters to independent test points and compare transformed coordinates with known reference values.
* Assess residuals, RMS error, and consistency across the dataset.

**Action 10.5:** Document the procedure and include the transformation parameters in international standards.

*Guidance:*

* Create a publicly available document which describes the process used to compute the transformation parameters.
* Include the transformation parameters in EPSG, ISO Geodetic Register and national geodetic agency standards.
* Include metadata on data sources, accuracy, and methodology.
* Ensure enough information is available so that the results are reproducible and publicly accessible if needed.

1. Develop plate motion, distortion or deformation model

In some situations, a 7-parameter transformation is not sufficient to accurately transform between the old geodetic datum and new geodetic datum. In these cases, a plate motion model, deformation or distortion model may be required for high accuracy applications. For example:

* Non-Rigid Deformation in the Source or Target Datum: If the transformation involves a region with tectonic movement, subsidence, or other deformations, a simple 7-parameter transformation cannot model local distortions.
* Significant Local Distortions in the Old Datum: Older geodetic datums often have inconsistent distortions due to inaccurate original surveys.
* Plate motion: A 7-parameter transformation does not account for ongoing plate tectonic motion which can be significant in some regions.

**Action 11.1:** Decide whether or not a plate motion distortion or deformation model is required.

**Action 11.2:** If required, create a plate motion distortion or deformation model.

*Guidance:*

* For guidance on the development of a 2D plate motion model, please refer to Section 7.2 of the Australian Geospatial Reference System Compendium <https://www.icsm.gov.au/publications/australian-geospatial-reference-system-compendium>.
* For guidance on the development of a 2D distortion model, please refer to Appendix B of the Australian Geospatial Reference System Compendium <https://www.icsm.gov.au/publications/australian-geospatial-reference-system-compendium>.
* For guidance on the development of a 3D deformation model, please refer to New Zealand Geodetic Datum 2000 deformation model <https://www.linz.govt.nz/guidance/geodetic-system/coordinate-systems-used-new-zealand/geodetic-datums/new-zealand-geodetic-datum-2000-nzgd2000/new-zealand-geodetic-datum-2000-deformation-model>.

1. Developing a physical height datum

A physical height system is a theoretical framework that defines how heights are measured and referenced. It includes:

* Reference Surface: The physical model used as a zero-height reference (e.g., geoid).
* Definition of Heights: Specifies whether heights are orthometric, normal etc.
* Computation Method: Defines how heights are derived (e.g., spirit levelling, gravimetric models).

Examples of Height Systems:

* Orthometric Height System – An orthometric height system is a height reference system where heights are measured above the geoid along the direction of gravity. It is the most common system used for surveying, mapping, and engineering because it represents "physical heights" that correspond to the flow of water (i.e., how gravity influences elevation).
* Normal Height System – A normal height system is a height reference system that approximates the orthometric height system but is computationally simpler and widely used in Europe and some other regions. It is based on the concept of normal gravity rather than actual gravity variations along the plumb line.

A physical height datum is a realized, physical reference used to assign heights within a height system. It is the practical implementation of a height system.

* Typically based on a benchmark (physical point) where height = 0 is defined.
* Can be determined from tide gauges (mean sea level) or a geoid model.
* Often regional or national, meaning different countries may have different height datums.

Examples of Height Datums:

* North American Vertical Datum of 1988 (NAVD88) – Used in the U.S. (orthometric heights).
* European Vertical Reference Frame (EVRF2019) – Used in many European countries (normal heights).
* Australian Height Datum (AHD) – Based on mean sea level at tide gauges (normal-orthometric heights).

**Action 12.1:** Choose a height system and height datum to adopt

*Guidance:*

* Identify the most important height applications in your country by reviewing the stakeholder requirements. Be sure to consider both the land and marine requirements.
* Consider how good the gravity data in your country is. If your country has limited gravity data, a datum based on the normal height system may be easier to implement and maintain as it doesn’t require detailed crustal density models that a datum based on the orthometric height system would.
* When choosing a physical height datum (the realization of the height system), you need to choose a zero-reference level which could be:
  + Mean Sea Level (MSL) from Tide Gauges: Traditional approach but varies over time.
  + Geoid-Based Datum: Modern and gravity-consistent, reduces sea level variations.
* After you have chosen a zero-reference level for the height datum, consider how people will access / use the height datum. Traditionally this was done using high accuracy levelling to propagate physical heights from the reference points (e.g. tide gauges) to survey benchmarks around a country. In the case of geoid based datums, this can be done by GNSS observations and the application of a geoid model to convert the ellipsoidal heights into physical heights.
* You should also consider:
* The benefits of maintaining consistency with neighbouring country height datums.
  + Maintaining legacy datums for legal and cadastral continuity.
  + Providing data conversation and transformation models between old and new datums.
* For more detailed guidance on height datums and height systems please refer to Part C: Physical Geodesy of the Australian Geospatial Reference System Compendium <https://www.icsm.gov.au/publications/australian-geospatial-reference-system-compendium>.
* Review the presentation Height Datums and Geoid Models from UN-GGCE Capacity Development Workshop <https://ggim.un.org/UNGGCE/documents/3_2_1%20-%20Height%20Datums%20and%20Geoid%20Models.pptx>

**Action 12.2:** Document the procedure and include the height datum in international standards.

*Guidance:*

* Create a publicly available document which describes the process used to compute the transformation parameters.
* Include the datum information in EPSG, ISO Geodetic Register and national geodetic agency standards.
* Include metadata on data sources, accuracy, and methodology.
* Ensure enough information is available so that the results are reproducible and publicly accessible if needed.

1. Update legal and policy documents

When countries update their geodetic and physical datums, they must consider several policy and legal factors to ensure a smooth transition and maintain continuity in national infrastructure, legal systems, and geospatial applications.

**Action 13.1:** Work with the project planning team to address the following questions.

* Does your country have legislation, regulations or policies which need to be updated to officially recognise the new datums?
* How will the changes impact legal consistency in land titles, cadastral records, and boundary definitions?
* Have you engaged sufficiently with stakeholders in land surveying, infrastructure, defence, and emergency response?
* Have you provided adequate guidance on how stakeholders can use the new datum or transition to the new datum?
* Will the change cause discrepancies in border definitions by coordinating with adjacent countries?

Appendix A: Geodesy Factbook

Document in development– to be circulated later.

Appendix B: Communications Plan (Example)

Scope

This communications strategy addresses how to engage and communicate with stakeholders on the *Upgrade to the Country Geospatial Reference System (GRS)* (the upgrade). Through a planned approach, the communication aims to:

* Increase awareness about the upgrade
* Provide education material about:
  + why the upgrade is necessary
  + what is being upgraded
  + when the upgrades are occurring
  + who is leading the upgrade
  + how to get more information and specific advice on a particular question/issue
* Actively engage with audiences through a variety of channels

Who is leading the communications?

The Country Steering Committee Chaired by \_\_\_ with representatives from \_\_\_.

Who is audience for the communications?

The audience for the communications are those affected by changes to GRS. These fit into the following broad categories.

Highly Influential

* Government agencies \_\_\_
* Government level working groups / committees \_\_\_ due to their reliance on positioning
* University lecturers from \_\_\_
* Professional spatial and surveying organisations including \_\_\_
* Software application developers such as \_\_\_
* Media including \_\_\_

Moderately Influential

* Government agencies \_\_\_
* Emerging industries using spatial data (e.g. Intelligent Transport, Location Based Services)
* Suppliers/Aggregators of spatial data (e.g. Google, Apple, Here)
* Standards Community (e.g. ISO TC/211, OGC)
* Non-spatial media from other connected communities (e.g. Building Information Modelling, app development, ICT, FME)
* Public

Background

What is a Geospatial Reference System?

The Geospatial Reference System of a country includes a number of elements (Figure 1) including:

* Datums or reference frames
  + Geometric datums (e.g. geocentric datums)
  + Physical datums (e.g. height datums)
* Transformation and Conversion Methods to transform from one datum to another
* Standards to ensure positioning information is Findable, Accessible, Interoperable and Reusable (e.g., EPSG, ISO).
* Infrastructure, including a national network of Global Navigation Satellite System Continuously Operating Reference Stations and survey marks to provide an authoritative and accurate network in support of positioning applications.
* A modern GRS has a geometric datum aligned to a recent realization of the International Terrestrial Reference Frame (ITRF) and a physical datum which has a well-defined connection to the International Height Reference Frame (IHRF).
* The GRS of a country can be applied to:
  + define latitude, longitude, height, orientation and gravity;
  + model dynamic, geophysical processes that affect geospatial measurements;
  + transform and convert data; and
  + ensure positioning information is Findable, Accessible, Interoperable and Reusable.

Without a national GRS, which is closely aligned to ITRF, geospatial data is inconsistent and unreliable, limiting the ability of Member States to understand and address complex challenges.

The accuracy of a country’s GRS impacts on its capability and capacity to collect and manage nationally integrated geospatial information and make evidence-based decisions and policies. In addition to the traditional survey, mapping and navigation fields, an accurate GRS is essential for Earth sciences, economic development and sustainability, public safety and disaster management, land and water administration, and environmental management.

Upgrades to the Country Geospatial Reference System

*Guidance:*

* Based on the feedback from stakeholders, explain why an upgrade to some or all of the GRS is needed from a business perspective.
* For example, which government agencies or industries are unable to do something because the datum isn’t accurate enough? What will an upgrade to the GRS provide for the country? What is the cost-benefit analysis of doing this work?

Who is leading the upgrade process?

*Guidance:*

* Explain the Steering Committee and Working Groups which have been established.
* Explain the role these groups will play,

Communication Objectives

* Attract the attention of stakeholders who will be impacted by the upgrade.
* Provide information that is clear, accurate, responsive, consistent and concise.
* Use various communication channels to reach the range of stakeholder groups.
* Provide clear and concise communication to help ensure call to action is clear, concerns are addressed as early as possible, and pre-empt any questions that may be asked.

Communication Outcomes

* Project partners are kept informed on the progress of the project.
* Stakeholders have the information required to implement the upgrade.

Project Owner

Responsible Leads:

Advisors:

Project Partners

|  |  |
| --- | --- |
| Project Partner | Involvement |
|  |  |
|  |  |
|  |  |
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Key Messages

*Guidance:*

* These are some examples how key messages can be adopted depending on the audience:
* To the Minister: "Updating our static datum is crucial for enhancing national infrastructure, improving disaster management, and ensuring our geospatial data aligns with international standards, ultimately driving economic growth and national security."
* To the General Public: "A new static datum will provide more accurate maps and location services, improving everyday activities like navigation, property boundaries, and emergency response, making our communities safer and more efficient."
* Agriculture Sector: "Adopting a new static datum will enhance precision farming techniques, leading to better crop management, optimized resource use, and increased agricultural productivity, benefiting both farmers and the environment."
* Healthcare Sector: "A new static datum will improve the accuracy of health data mapping, enhancing disease tracking, emergency response, and healthcare planning, ultimately leading to better public health outcomes."
* Transportation Sector: "Updating our static datum will lead to more precise navigation systems, improved infrastructure planning, and safer, more efficient transportation networks."
* Environmental Sector: "A new static datum will provide more accurate environmental data, aiding in better monitoring of natural resources, climate change impacts, and conservation efforts."
* Urban Planning Sector: "Adopting a new static datum will enhance urban planning and development, ensuring more accurate land use data, better infrastructure design, and improved public services."
* Utilities Sector: "Updating our static datum will improve the accuracy of utility mapping, leading to better management of resources like water, electricity, and gas, and reducing the risk of service disruptions."

Appendix C: Airborne Gravity Business Case Example

Key Information

**Description of the project**

1. The objective of the project is to collect consistent and evenly distributed airborne gravity data over regions of Victoria for the primary purpose of improving height determination from GPS positioning.
2. Airborne gravity data is required to significantly improve the gravity model (known as the gravimetric quasigeoid model) which enables height determination from GPS devices.
3. The current version of the gravity model has an uncertainty of five to eight centimetres. The airborne gravity data will reduce the uncertainty of the model to one to three centimetres.
4. Airborne gravity data is required over targeted regions of Victoria, including:
   * Greater Melbourne, where there is a lack of consistent gravity data offshore and across Port Phillip Bay. The unreliable data has a degradation effect on the gravity model onshore around Melbourne and the central Victorian coastline, where the model is required to be as reliable and accurate as possible.
   * Eastern Victoria, where the gravity field is poorly sampled due to sparse gravity station coverage and in places low accuracy gravity observations attributed to difficulties with access and accurate observation in mountainous and forested areas.
5. The airborne gravity data only needs to be collected once for the gravity model. This is a one-off procurement that will provide benefits to Victoria now and into the future.
6. The airborne gravity surveys will involve overflight of large regions of Victoria.
7. During survey operations, a small fixed-wing aircraft carrying a specialised gravimeter will fly along lines one to two kilometres apart.
8. The survey altitude above ground level will be above the general aviation airspace threshold of 150 metres nominated by the Civil Aviation Safety Authority (CASA). The contractor is also obliged to comply with other CASA regulations (e.g., increase of flying height over built-up areas to above the CASA threshold of 300 metres).
9. The airborne gravity surveys will not involve any disturbance to the ground.
10. The project agreement includes a requirement for GA to ensure the contractor performing the airborne gravity surveys will satisfy the requirements of an independent air safety audit.
11. The gravimeter fitted to the aircraft detects subtle differences in the force of gravity due to the different rocks in the earth below. The instrument is referred to as passive, in that it does not emit any signal, and does not have any impact on people or animals.
12. DELWP will coordinate the stakeholder engagement associated with the airborne gravity surveys.
13. A stakeholder engagement plan has been prepared for the airborne gravity surveys (**Attachment 3**).
14. It is the intention of DELWP, DJPR and GA to notify stakeholders who may be involved in activities that might impact or be impacted by the airborne gravity surveys.
15. A diverse range of land types will be covered in the airborne surveys, including built-up urban areas, regional areas, pastoral leases, native title determined and claim areas, mining operations, and national and state parks and reserves.
16. DELWP will coordinate the stakeholder engagement actions, which include a media release announcing the project prior to survey operations and targeted notification of selected stakeholders (such as local government, farming associations, Registered Aboriginal Parties, Victoria Police, parks and reserves managers).
17. The contractor will be required to arrange all communications necessary to ensure safe aircraft operations.

**Project Justification**

1. Height determination from GPS is important due to the increased reliance and expectations of GPS positioning across business and our society.
2. GPS positioning technology is rapidly improving in terms of accuracy and reliability. In the 2018-19 federal budget the Australian Government invested $224.9 million into precise positioning for Australia. DELWP is contributing to this ‘Positioning Australia’ initiative, which is expected to deliver three centimetre accuracy positioning anywhere in Australia where there is mobile coverage and ten centimetre accuracy everywhere else.
3. To capitalise on these advancements in GPS positioning technology, it is important that the gravity model, which enables determination of real-world heights, is as accurate and reliable as possible.
4. GPS positioning is becoming more accessible, encouraging innovation in existing and emerging applications, many of which require accurate height information. For example:
   * Modern surveying practices use GPS and the gravity model to measure heights to support construction and development activities, particularly those related to the management of water.
   * Aerial mapping (e.g. LiDAR) depends on the gravity model and GPS positioning to create elevation models (e.g. DTM).
   * Elevation models are an essential component in development planning, water and coastal management and environmental risk analysis (e.g. flooding, sea level rise and bushfire risk).
   * A wide range of applications (e.g. construction, planning, agriculture, transport, emergency services) will be enhanced by improved GPS heighting and interacting with improved elevation models and mapping products.
5. Australia is preparing to implement a modernised national height reference frame based entirely on the national gravity model.
6. The capture of additional gravity data and improvement of the gravity model is required to ensure Victoria is prepared to adopt the new national height reference frame and deliver the full benefits.
7. The current national height reference frame, the Australian Height Datum 1971 (AHD71), is based on mean sea level from the late 1960s, contains many errors and is cumbersome when interacting with GPS positioning technology.
8. The new, national gravity model-based height reference frame will operate seamlessly with GPS technology and support consistent, accurate and reliable height determination across Australia.
9. Modernised national height reference frames based on gravity models are being adopted internationally (Canada, New Zealand and USA). In each country, additional airborne gravity data were captured to enhance the gravity model prior to release.
10. Victoria, through DELWP, is leading Australia with these targeted airborne gravity surveys for the purpose of enhancing the gravity model and improving height determination from GPS positioning.
11. The gravity data will also contribute to geophysical and geological mapping applications.
12. GA maintain a national database of gravity data which includes a combination of land-based and airborne gravity data collected over many decades, most of which was captured to support geophysical and geological mapping.
13. GSV (DJPR) have procured airborne gravity data over the Gippsland and Western Victoria Coastlines to support geophysical and geological mapping.
14. Recognising the shared interest in the airborne gravity data and benefits of collaboration, GSV (DJPR) are contributing funding to this project, particularly to densify the gravity data capture over Eastern Victoria.
15. Gravity surveys provide benefits to additional applications, including to:
    * enable land managers to obtain a broad knowledge of ground water stores;
    * assist engineers identify major natural hazards; and
    * support mineral and energy exploration companies decide where to explore.

Context

1. Geodesy, within SGV, are responsible for managing the infrastructure, services and spatial reference frames that enable high accuracy positioning for the benefit of the Victorian community. This includes the development, ongoing maintenance and enhancement of the reference frame for height.
2. Geodesy provide access to the national height reference frame through physical infrastructure and digital information, including:
   * network of more than 100 GPS reference stations providing real-time satellite positioning services across Victoria;
   * network of more than 40,000 ground-based survey control marks with accurate coordinate information.
3. These services rely on the gravity model to provide customers with easy access to accurate height information aligned to the national height reference frame.
4. Other groups within SLAI also deliver spatial products (e.g. Vicmap suite of elevation products) which depend on height information derived from the gravity model and connections to the survey control mark network. These include contour, digital terrain and elevation models which are widely used by government and industry.
5. The current gravity model, known as AUSGeoid2020, has been manipulated to approximate the current national height reference frame (AHD71) and has an uncertainty in excess of ten centimetres.
6. The AUSGeoid2020 model is a national product developed by GA that enables derivation of AHD71 heights from GPS positioning.
7. The model consists of a gravimetric component based on gravity measurements and a geometric component.
8. Geodesy, within SGV, contributed to the development of the geometric component of the model by supplying more than 300 survey control marks with accurate AHD71 heights and GPS ellipsoidal heights.
9. The AUSGeoid2020 model has an uncertainty in excess of ten centimetres. Surveyors must perform data manipulation strategies (e.g. site transformation) to improve the consistency of GPS derived heights with local survey control marks.
10. The gravity data used in the development of the AUSGeoid2020 model has been obtained primarily for geophysical and geological mapping applications. Users of GPS positioning have benefited substantially from the secondary use of this data to support height determination from GPS positioning.
11. GA have extensive experience in the acquisition of airborne geophysical data and will manage the procurement and acquisition of the airborne gravity survey data.
12. DELWP, DJPR and GA will collaboratively design the airborne gravity surveys and develop the open tender Request for Tender (RFT) specifications.
13. Modifications to project area extents may be required, depending on available funding and tender submissions.
14. GA will manage the procurement, in accordance with Commonwealth Procurement Rules, engage contractor and manage the acquisition of airborne gravity survey data.
15. DELWP, DJPR and GA will all be involved in the tender evaluation process, detailed in the project agreement.
16. Data obtained from the airborne gravity surveys (including all intellectual property rights in the data) will be the property of the State of Victoria through DELWP and DJPR.
17. DELWP and DJPR will make all airborne gravity data created as part of the project widely available via the gravity database managed by GA.

Consultation

1. DELWP, DJPR and GA contributed to development of the NCF project agreement and stakeholder engagement plan, with approval from LUV Legal, DELWP procurement and SLAI stakeholder engagement personnel.
2. GA and DJPR were also consulted during the preparation of this brief.
3. GSV have prepared a similar brief to the Secretary of DJPR.

Attachments

|  |  |
| --- | --- |
| **No.** | **Attachment name** |
| 1 | National collaboration framework project agreement (2020/828) |
| 2 | National collaboration framework collaborative head agreement (Ref: CMCG4003F-000881-1) |
| 3 | Stakeholder engagement plan |

1. UN General Assembly Resolution 69/266, 2015, <https://ggim.un.org/documents/a_res_69_266_e.pdf> accessed 28 May 2024. [↑](#footnote-ref-2)